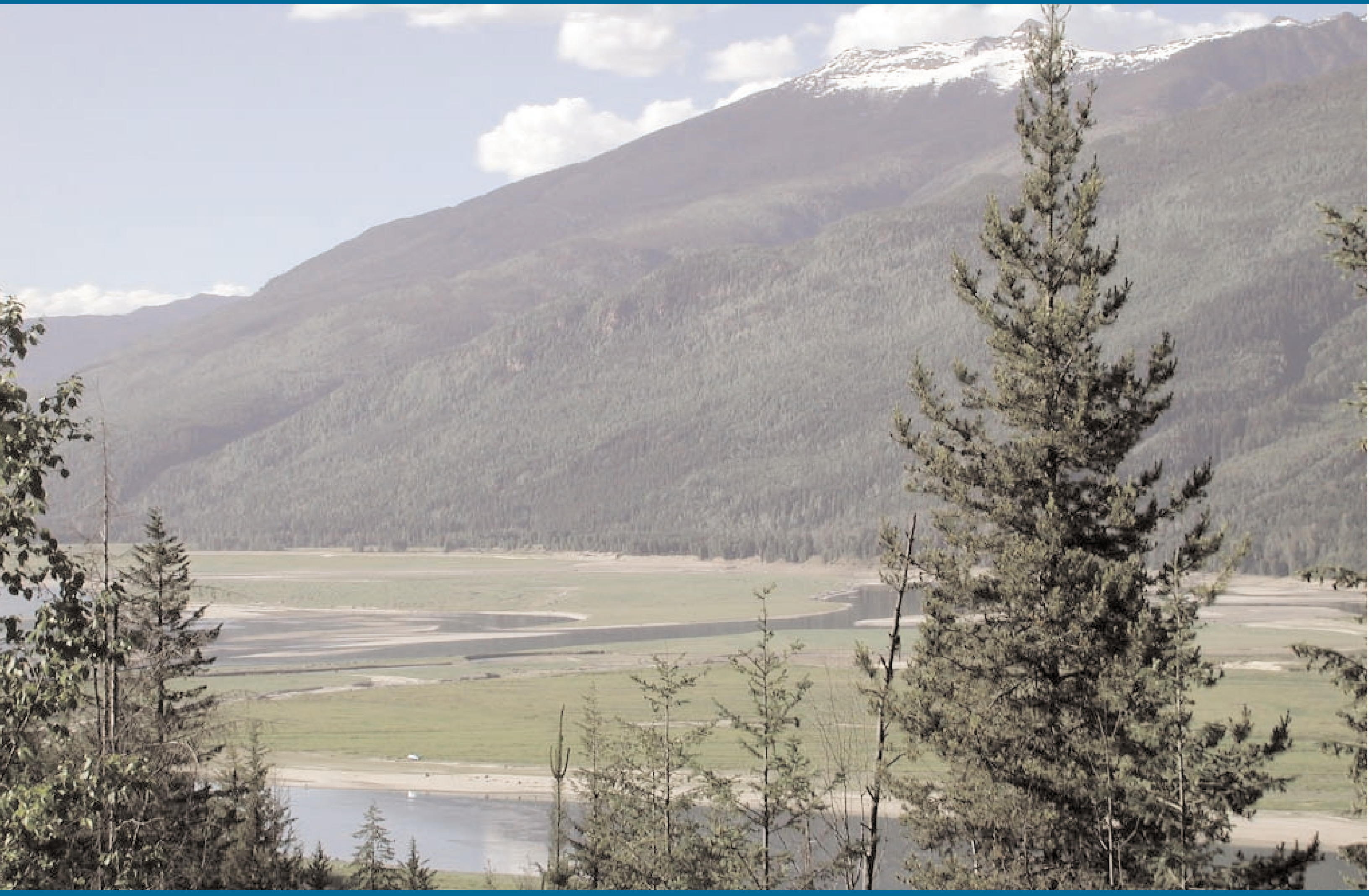
Evaluation of Ancillary Benefits of Reservoir Drawdown Zone Revegetation in the Upper Arrow Reservoir: Overview Report

May 2003



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Evaluation of the Ancillary Benefits of Upper Arrow Reservoir Drawdown Zone Revegetation Project

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Strategic Environmental Initiatives Program: Evaluation of Ancillary Benefits of Reservoir Shoreline Revegetation in the Upper Arrow Reservoir

Overview Report

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May 2003

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Executive Summary

Background

In 1998, BC Hydro, through its Strategic Environmental Initiatives Program (SEIP) initiated a three-year pilot study to assess ancillary benefits associated with revegetation of parts of the Upper Arrow Reservoir drawdown zone that had been seeded to control dust. While the original focus of the study was on aquatic productivity, it was expanded to include benefits to wildlife, aesthetics and recreation. The first year of the project was a pilot year to examine a number of approaches to analyzing benefits and testing field methodologies. Years two and three of the project involved completing field studies, detailed mapping, ecological modelling and final report preparation.

Funding for the project was provided by Fisheries Renewal BC and BC Hydro's Strategic Environmental Initiatives Program.

The value of this project has included:

1. Confirming the ancillary benefits of shoreline revegetation in the drawdown zone of the Upper Arrow Reservoir. These include:
    - increased aquatic biodiversity
    - provision of habitat and food for fish and wildlife
    - increased aquatic productivity
    - improved aesthetic benefits
    - additional recreational benefits
    - increased wildlife habitat diversity
    - increased opportunities for carbon sequestration

2. Creating a greater scientific understanding of interactions between reservoir operations (water levels), vegetation community development, nutrients and biomass production. This information is extremely valuable for transfer to other reservoir systems where the establishment of vegetation is an issue. In addition, the study generated an ecological model that demonstrates and explains these interactions. Subsequently, the model was adapted for use in Water Use Planning in the Bridge-Seton, and Columbia River systems.

3. Producing a range of mapping products, GIS, Digital Elevation Model and other data for the Upper Arrow Reservoir that can be accessed by a wide range of users.

4. Opportunities for applying lessons learned and experimental design to other reservoirs, particularly in relation to dust control methods, vegetation establishment and monitoring, digital mapping, orthophotography, and ecological modelling.

5. Generating and disseminating comprehensive information for the public, reservoir managers and researchers (i.e., public and technical reports, databases and CD-ROM). The information has the capacity to be web-based for even greater distribution.

Key Findings

The following key findings and recommendations are drawn from the individual research studies. We have taken the liberty of condensing the findings and recommendations and assume responsibility for any errors or omissions. For full report recommendations, please refer to Section 8.

Vegetation and Soil Studies

AIM Ecological Consultants Ltd. and CARR Environmental Consultants, *Summary Report on Vegetation and Soil Analyses for the 1999 Pilot Study, Revelstoke Reach-Upper Arrow Reservoir May 2000*

CARR Environmental Consultants and AIM Ecological Consultants Ltd. *Quantification of Vegetation Inputs to Revelstoke Reach, Summary of 2000 Field Program – Vegetation and Soil Analyses*. July 2002.

CARR Environmental Consultants and AIM Ecological Consultants Ltd. *Synthesis of Vegetation and Soil Studies For Revelstoke Reach - Upper Arrow Reservoir. May 2002.*

Anne Moody, AIM Ecological Consultants Ltd. *Long-Term Monitoring of Vegetation Expansion and Trials in the Dust Control Treatment Areas of Revelstoke Reach - Upper Arrow Reservoir*. May 2002.

AIM Ecological Consultants Ltd. in association with Eco-Logic Ltd. and CARR Environmental Consultants. *Vegetation Benefits to Fish: A Literature Review.* April 2000.

- CARR Environmental Consultants and Aim Ecological Consultants Ltd. undertook a two-year field program in 1999 to quantify the distribution and abundance of permanent native vegetation in the reseeded portions (dust control areas) of the Upper Arrow Reservoir.
- Plant communities were identified and plant and root biomass (above and below ground) was determined
- Due to the extreme stresses imposed on the plants by the inundation regime, the vegetation which has evolved in the reservoir area is limited to a very few species which are tolerant of extreme flooding and exposure. Reed canarygrass and lenticulate sedge are the two dominant wetland species throughout the permanently recolonized zone, with both species heavily influenced by reservoir elevation.
- The growth performance of the vegetation in terms of biomass and nutrient status also appears to be sensitive to elevation change for all species. On a per unit area basis ($g.m^{-2}$), the lenticulate sedge is by far the highest biomass producer and highest net exporter of vegetation into the aquatic environment during inundation. Production of the reed canarygrass and Columbia sedge is similar, with the reed canarygrass's contribution to the ecosystem far greater due to its dominant presence throughout the area.

Vegetation and Fish Literature Review

AIM Ecological Consultants Ltd., Eco-Logic Ltd., and CARR Environmental Consultants. *Vegetation Benefits to Fish: A Literature Review*. April, 2000.

AIM Ecological Consultants Ltd. in association with Eco-Logic Ltd., and CARR Environmental Consultants undertook a literature review to document previous studies that would:

- quantify the role of vegetation in aquatic ecosystem productivity, in particular fish;
- identify the relationship between aquatic vegetative growth and decomposition to fish productivity, and other contributors to the food web; and,
- focus on reservoirs, but include relevant information from lake and other aquatic environments.

- Relevant reservoir, fish and vegetation studies were reviewed from a broad north temperate perspective, with specific reference to the B.C. situation whenever possible. General principles, as they related to the "potential" benefits of vegetation to fish were included from studies not directly applicable to B.C. Much of the existing literature was not directly related to the climatic conditions, native plant species or fish populations existing in B.C. Reservoirs have received limited ecological and limnological attention compared to natural waterbodies. Very little relevant research has been conducted in Canadian reservoirs or wetlands.

- Reservoirs generally have a scarcity of littoral vegetation largely because of annual water level fluctuations. The resulting lack of cover from aquatic vegetation may increase predation on small fish. These fluctuations may also result in reduced littoral productivity and decreased growth rates in fish.

- Aquatic invertebrates provide the critical ecosystem linkages in energy, nutrient and carbon flows between primary producers, microbial assemblages and higher consumers such as fish and waterfowl. Aquatic plants have been shown to positively alter conditions of water velocity, substrate, detritus (food) availability, etc. for invertebrates. Aquatic invertebrate populations are significantly higher in vegetated sites compared to non-vegetated sites.

Vegetation Mapping

Anne Moody, AIM Ecological Consultants Ltd. *Vegetation Mapping (1968-2000) of Dust Control Treatment Areas, Revelstoke Reach - Upper Arrow Reservoir*, March 2002

- AIM Ecological Consultants Ltd. undertook an analysis of vegetation growth in the Upper Arrow Reservoir based on air photo interpretation. It was found that in the 10 year period following creation of the Upper Arrow Reservoir in 1967 there was an 89% reduction in vegetation cover within the study area (See Map 1). A 42% increase in vegetated cover was observed in the total vegetated area (from 120 to 170 ha) between 1977 and 1991, followed by an almost 200% increase between 1991 and 2000. This dramatic increase in native, perennial vegetated cover has been attributed to factors associated with the annual fall-rye drill-seeding operations.

- The year 2000 mapping revealed that perennial vegetation now dominates about 500 ha of the study area. Three major vegetation groupings, in addition to the annually seeded fall rye, account for most of the current vegetation. These include the communities dominated by grasses, sedges and horsetails. The grass group dominates 75% of the mapped areas, followed by sedge (19%) and horsetail (6%). The perennial wetland vegetation occupying the study area in the year 2000 is a substantial increase over the pre-impoundment floodplain and wetland vegetation types which occupied 365 ha in 1968.

Biofilm, Invertebrate and Fish Communities Study

Limnotek Research and Development Inc., RL&L Environmental Services Ltd. and Eco-Logic Ltd. *Biofilm, Invertebrate and Fish Communities Associated With Vegetation Strata in the Drawdown Zone of the Arrow Lake Reservoir. 1999 Data Report.* March 31, 2000

Limnotek Research and Development Inc., Golder Associates (RL&L Ltd). and Eco-Logic Ltd. *Biofilm, Invertebrate and Fish Communities Associated With Vegetation Strata in the Drawdown Zone of the Arrow Lake Reservoir. Final Report.* March 2002

- Limnotek Research and Development Inc., Golder Associates, (RL&L Environmental Services Ltd.) and Eco-Logic Ltd. conducted a study to examine the effect of submersed vegetation on the abundance and composition of periphyton, benthic invertebrates, and fish in the drawdown zone of Revelstoke Reach in the Arrow Lakes Reservoir. Periphyton on all plants was comprised mainly of diatoms and filamentous green algae. Densities on leaves were <18,000 cells/cm^2 and most were <6000 cells/cm^2. In comparison to other oligotrophic systems, these densities were extremely low. Lab methods used to remove confounding effects of extensive silt and sand in the samples were found to yield underestimates of actual cell densities.

- A total of 66 benthic invertebrate taxa including naidid, enchytrid, and lumbriculid worms, nematodes, ostracods, tubificids, water mites, gastropods, aquatic insects, beetles, terrestrial insects, zooplankton, and freshwater shrimp were found in aboveground and belowground plant samples. Most abundant were the oligochaete worms, nematodes and ostracods. Benthos densities reached 43,727 animals·m^{-2} in aboveground samples and almost 64,000 animals·m^{-2} in belowground samples. These densities were very high compared to those in other oligotrophic systems.

- Vegetation establishment increased the areal biomass of benthic invertebrates by two to four times over that found in barren soils. The submersed vegetation greatly increased the areal extent of substrata for colonization by benthos, allowing a diverse and abundant fauna to flourish.

- Sucker species that are mainly detritivous feeders may have responded to increased benthos in association with dead and decaying fall rye but no link was found between the plant – benthos association and rainbow trout that are mainly visual predators. All rainbow trout were eating mainly terrestrial invertebrates that landed on the water surface. There was no evidence of these fish eating taxa found in association with the plant substrata.

Wildlife Studies

The wildlife component of the project consisted of three studies: songbird use of vegetation habitats, songbird banding and a survey of waterbird use of the Upper Arrow Reservoir.

Songbird Use of Four Floodplain Vegetation Types

Boulanger, John, John G. Woods and Janice Jarvis. *Songbird Use of Four Floodplain Vegetation Types in the Revelstoke Reach, Upper Arrow Reservoir, British Columbia, Canada.* April 2002.

- Boulanger, Woods and Jarvis (2002) surveyed the bird use of 4 terrestrial vegetation types within the flooding zone of the Upper Arrow Reservoir during a year of lower flood elevations (below 430m) Fifty-meter fixed distance point counts were conducted at sampling sites stratified by vegetation type during 5 periods between 16 May and 31 July 2001. Simultaneous sound recordings during the counts allowed later verification of observer results.

- Seventy-four species of birds were recorded within 50 m radius of the survey points and 12 additional species were seen within the floodplain but not within any 50 m point count. In terms of species richness, species diversity, and bird abundance, cottonwood and willow habitats received more use than planted Fall Rye or native grass habitats.

- Cumulative bird lists for each habitat included: 54 species in cottonwood habitat; 47 species in willow habitat; 35 species in native grasses habitat; and, 32 species in planted Fall Rye habitat. Analysis results suggest that cottonwood and willow habitat types had the highest number of species occurring during surveys when compared to native grass and planted rye. In addition, cottonwood and willow habitat types had the highest density of birds, and highest species diversity of habitat types surveyed.

Columbia River-Revelstoke Migration Monitoring Station Banding

Jarvis, Janice. *Columbia River-Revelstoke Migration Monitoring Station Final Banding Report For 2001.* 2002.

- The Canadian Wildlife Service (CWS), Parks Canada, and Friends of Mount Revelstoke and Glacier established the Columbia River-Revelstoke Migration Monitoring Station (CRR) in 1998 to track land bird migration activity and provide information on their migration and habitat needs while involving the local community. The CRR station has run since 1998 as a trial project with the goal of setting up a long-term monitoring station that becomes part of the Canadian Migration Monitoring Network (CMMN). The CRR completed the 4^{th} year of operations banding 2198 birds during the 2001 fall migration-banding season.

The CRR station completed 4 successful years of fall migration monitoring in 2001. Because this CRR station is located in a functioning reservoir, it presents different challenges compared with other migration monitoring stations. The past 4 years have seen various water levels from high (1999/2000) to low (2001); even-though the station may be subject to flooding and potentially reduce the number of days and nets used in a season, this location is still the first choice for a migration monitoring station on this stretch of the Columbia River.

Waterbirds of the Revelstoke Reach Wetlands

Jarvis, Janice and John G. Woods. *Waterbirds of the Revelstoke Reach Wetlands, Upper Arrow Reservoir, Revelstoke, British Columbia, Canada.* June 2001.

- Jarvis and Woods summarized 10 years of waterbird survey data in the Upper Arrow Reservoir. From January 1991 to March 2001 waterbirds were surveyed from fixed points along 12 kilometers of the eastern shoreline of the northern portion of Upper Arrow Reservoir, known as the Revelstoke Reach wetlands. These surveys documented 65 species of waterbirds using the Reach with large variations in species richness and abundance by month and zone.

- The area with the greatest species richness and individual abundance had the most stable water regime. The greatest species diversity and individual abundance occurred during the spring and the least during the winter and summer.

- Several species appeared to be regular breeders but summer flooding may limit reproduction opportunities.

Ecological Model

Korman, Josh. *Simulating the Response of Aquatic and Riparian Productivity to Reservoir Operations: Description of the Vegetation and Littoral Components of BC Hydro's Integrated Response Model (IRM).* December 2002.

- Ecometric Research Inc. developed a simulation model, predicting the response of riparian vegetation and benthos produced in the littoral zone to water surface elevation schedules and fall rye planting in the Upper Arrow Reservoir.
- The intent of the modeling effort was to provide a predictive tool for water management and to highlight key gaps in data and understanding to strengthen future monitoring and research efforts. Model development was a collaborative effort that integrated data and hypotheses from vegetation ecologists and limnologists who were actively working in the Upper Arrow Reservoir as part of the SEIP Project.

Aesthetic and Recreational Benefits

Pedersen, Marc. *Upper Arrow Seeding and Recreation Study*. BC Hydro Research Services, August 2001.

McPhee, Michael. *Group and Organized Recreation Activities in the Upper Arrow Reservoir Drawdown Zone.* March 2002.

- A telephone survey of 400 Revelstoke residents was undertaken in 2001 to determine perceptions of the seeding program as well as the type, location and participation rates of residents in recreational activities that occur in the Upper Arrow Reservoir. Representatives of recreation clubs in Revelstoke were also interviewed to determine their recreational activities within the Upper Arrow Reservoir.

- The revegetation program has had a positive impact from an aesthetic and recreation standpoint. According to many of those surveyed, the revegetation program has resulted in a more pleasant area and a positive recreation experience (less dust, more green areas) and some of those interviewed claim that the vegetation growth in the reservoir has led to an increase in birds, fish and other wildlife. In turn, this has led to an increase in recreation opportunities.

Conclusions

- The SEIP project has contributed to an understanding of the complexities between reservoir operations and related vegetation growth, aquatic, wildlife, aesthetic and recreational interactions.

- The project was challenging and revealed that careful thought must be given to study objectives, design and data collection methods. Research in active operating reservoirs is also a challenge because conditions can change rapidly (i.e., water level rise).

- The study period was relatively short, field operations were restricted, and water levels from year to year were quite different. This created problems for study design, data acquisition and comparisons.

- There is a better understanding of the interactions between water levels, plant growth rates (by species and elevations), and biomass and aquatic productivity. There is potential for applying this research to understanding carbon accumulation in reservoir systems. It is also clear that recreational activities are an important component of reservoir operations and that the seeding program and native vegetation growth have contributed to the enjoyment of recreational pursuits.

- This study has made a positive contribution to the broader resource management decisions that are part of Water Use Planning. Water Use Plans have direct implications for reservoir operations and through this study, information has been generated that will assist BC Hydro in further understanding the relationships between reservoir operations, and ecological and social functions and processes.

Recommendations

Vegetation and Mapping

- Continued assessment of the soil/vegetation carbon pool may be warranted. Other parameters associated with the new wetlands, such as biomass and nutrient distribution, provide important information on this new type of ecosystem and should be part of a long-term monitoring program if BCH wishes to contribute to the science of drawdown zone enhancement.
- Both the airphoto assessment (AIM, 2001) and field sampling program undertaken in 2000/2001 have provided a test of methods that should be incorporated into a long-term monitoring program. This type of monitoring should be conducted on a periodic basis, at a minimum of every five years, or at an accelerated time frame in response to a major shift in water management that lasts for three years (at this time believed to be the threshold where significant changes in plant establishment and spread are realized).
- The stratification of the vegetation communities using airphoto assessment is very important if (or when) a detailed assessment of biomass, nutrients, or soil parameters is required. The stratification will provide delineation of the detailed sampling units where the modified grid-point intercept method used in the 2000 field program can be applied. This type of approach will provide statistically valid determination of individual plant species presence and abundance within a specific plant community, key information to extrapolate subsequent data throughout the entire sampling area. Further detailed sampling of biomass, nutrients, or soil parameters should then focus on the dominant species found in each stratum.
- BC Hydro should clearly define the goals and objectives (as well as precision) of any future detailed sampling program because the cost of laboratory analysis can be considerable. The number of samples to be taken for each species and design of statistical analyses will be determined by the objectives and desired level of precision.
- BC Hydro should repeat aerial photography and vegetation mapping on a 5 year interval to monitor developing vegetation patterns within Revelstoke Reach, and extend the vegetation mapping to cover the remainder of the Upper Arrow draw down zone wetlands to obtain a complete record of the vegetated area within Revelstoke Reach.

Aquatic Community Productivity

- If the opportunity arises to repeat the 1999 experiment, it should include a longer period of sampling to determine if advanced development of the benthic community produces larger individuals and greater biomass than was found in 1999. Larger animals would potentially increase their availability to fish late in the growing season and increase the importance of vegetation establishment as a benefit to fish populations.
- . Local observations suggest that fish stranding may be closely linked to use of the drawdown zone by wildlife. For this reason, it may be important to link measurements of use of vegetated and non-vegetated areas by wildlife at different times of the year with measurements of fish stranding and total biomass produced in vegetation strata.

- A potential benefit of vegetation establishment in the spring months is that new and existing biomass may provide extensive habitat for terrestrial invertebrates. While these animals may directly provide food for birds, they may also be trapped with rising water later in the spring and summer. If this process happens, a pulse of food may be available for fish that follow the rising water into Revelstoke Reach. Evidence of the extent of this food supply may be measured with emergence traps or other sampling device capable of catching flying insects at the water surface. If there is interest to continue investigation of potential benefits to fish from revegetation of the drawdown zone, these measurements should be considered as part of future sampling activities.
- A potential consequence of vegetation establishment in drawdown zones is creation of a carbon sink. That sink may be in the form of permanent vegetation and associated soils or if plants die under water, it may be in the form of carbon taken up in vegetation and then translocated to the aquatic ecosystem to be fixed in other organic matter. Either of these processes or the combination of these processes may represent a significant carbon sink. Creation of large carbon sinks is desirable as a means to limit carbon loss to the atmosphere. The magnitude of such a sink may be determined with calculation of a carbon budget for the aquatic component of the Revelstoke Reach in which the fate of downstream transport of carbon is measured. These data may be coupled with existing work on development of a carbon budget for soils of the Revelstoke Reach.

Songbird Use of Vegetation Habitats

- Repeat these surveys during years with varying water conditions (e.g., “normal” years and “high” water years). The survey sites identified in 2001 could be used as base points for future sampling.
- Investigate the relationship between water levels, vegetation types, and bird forage production.
- For selected species, determine whether these reservoir habitats constitute “source” or “sink” populations.
- Attempt to sample more cottonwood and willow plots. Use of different numbers of plots complicates the comparison of species richness and species diversity of different areas. Therefore, if possible, the sample size of plots for each habitat type should be made more even. Alternatively, there are potential randomization methods to further account for uneven sample sizes between plots when assessing species diversity measures.
- Consider the use of distance methods if particular target species are of interest. Distance methods allow more robust estimation of species density. This method is much better suited for individual species rather than whole bird community analysis. The results of this study can be used to assess whether sample sizes are adequate to use distance methods for species of interest.
- Consider the measurement of other covariates besides habitat type, which might affect species diversity and abundance. Other covariates such as water levels, elevation, the stage of vegetation (i.e. leaf cover), and potentially insect abundance may allow further

explanation into differences between habitat types. The actual choice of covariates to measure should be based upon knowledge of factors that affect bird abundance.

- Consider estimation of movement of species between habitat types.

Songbird Banding

- The use of the area by landbirds must co-exist with reservoir operations, wildlife, fish, and recreational use. The data collected at the station is currently being used for the 'Water-Use Plan' for the Columbia River to look at future operations of the dams to avoid or reduce threats to migrating landbirds. The data gathered at the station will provide local residents and land-use managers a better understanding of the landbirds use and needs over time.

Ecological Modeling

- A vegetation monitoring program should track changes in vegetation and seedling establishment over time, and help establish key relationships between survival, growth and various management practices such as planting and water elevation schedules.

- Quantifying of changes in vegetation should be accomplished by repeat sampling of plots and interpretation of aerial photographs. The selection of sampling plots should be based on a random-stratified design with the strata being defined by key variables that control the establishment, growth, and survival of vegetation (elevation, fall planting intensity, substrate, aspect).

- A DEM for the monitoring area should be developed and colour photographs taken at a pre-determined intervals (e.g. every 3 yrs). The photographs for the DEM should be flown when the water surface elevation is at its lowest, usually in the early spring. For vegetation monitoring, the photographs should be taken early enough in the year to document before vegetation at lower elevations is flooded, but not too early so that vegetation has not had sufficient time to green-up. Ideally, field sampling of plots should be conducted close to the time air photographs are taken to assist in the interpretation.

- The monitoring program should contain an experimental component that allows estimation of certain model parameters that could not be achieved by the monitoring activities described above. Quantifying the effects of inundation on survival and growth of seedlings and mature plants could be accomplished by experimental planting at a range of elevations. These areas would be sampled over the growing season to determine the proportion of seedlings and mature plants that died under different inundation conditions (duration and depth) and how their growth was affected. Similar experiments could be conducted to estimate the effects of dry stress. The feasibility of performing these experiments in the field should be compared to the feasibility and utility of performing them under more controlled conditions that could be attained in a greenhouse.

- The bounds of the monitoring program should be carefully defined. The lateral and elevational extent of the monitoring area should include not only areas that are currently vegetated, but also include barren areas that have the potential to recover under conceivable planting and water management schedules. The types of vegetation to be monitored should be based on not only their dominance in the current community, but also on their importance to wildlife.

Recreation

- Recreation use of the revegetated areas should be monitored to ensure there is no damage to the established and newly established vegetation.

- Management of recreation uses may be required to ensure that sensitive wetland and wildlife areas are not impacted. This could involve establishing formal pathways or routes that avoid sensitive areas and limiting access in some areas or periods (e.g., bird ground nesting sites and seasons)

1.0 Introduction

The Arrow Lakes Reservoir is part of the Columbia River hydroelectric system, and is located between the Revelstoke and Hugh Keenleyside Dams. The Hugh Keenleyside Dam is located downstream from the Revelstoke facility and forms Arrow Lakes Reservoir. The dam was constructed in 1967 and Arrow Lakes Reservoir was filled to the maximum operating level by mid-1969.

Arrow Lakes Reservoir is about 240 km in length and has a surface area of about 465 km^2 at full pool. Prior to project development, it was two natural lakes (Upper and Lower Arrow) which had a maximum surface area of 393 km^2.

Prior to impoundment, the elevation of Arrow Lakes fluctuated between 420 and 427 m, representing a 7-8 m range in seasonal levels. The present operating regime of the reservoir creates fluctuations in water levels of up to 20 m. Formation of the reservoir has inundated much of the extensive flats at the northern end of the former Upper Arrow Lake and the bottom lands between the upper and lower lakes. Much of the reservoir is now steep sided and narrow with rocky shorelines and narrow gravel beaches. At low water levels, the reservoir is separated into two sections.

Runoff into the arrow Lakes Reservoir is primarily from snowmelt with over 70% of the annual runoff occurring from May to August. Rainfall is a minor contributor to the annual volume, but can produce high peak flows, particularly when it coincides with extreme snowmelt conditions. The reservoir is operated to capture as much water as possible during spring freshet within the maximum operating level. The annual cycle typically involves maximum levels at or below 440.1 m during July and August followed by minimum levels at or above 420.0 m during March and April.

A combination of the operating regime, light glacial sediments in the drawdown zone, and wind conditions resulted in recurring dust storms in Revelstoke following creation of the Arrow Lakes Reservoir. In the 1970's and 1980's, BC Hydro investigated several potential means of controlling the dust problem, including engineering approaches and revegetation. Eventually, seeding dust source areas with fall rye was identified as the preferred method for controlling dust.

Since the late 1980's, significant portions of the Revelstoke Reach of Arrow Lakes Reservoir (often referred to as Upper Arrow Reservoir) have been repeatedly seeded with fall rye for wind erosion control and dust abatement. Initially, only 200-350 ha of identified dust source area was seeded with fall rye. However this program was expanded to affect over 1000 ha in 1991. The seeding has continued for dust control annually, with the program modified each year based on projected water levels, shifts in dust source locations, and the encroachment/establishment of native vegetation on previously seeded areas. The shift in treatment areas as a result of native vegetation colonization has allowed the annual seeding program to address other identified dust source areas while leaving wind erosion control to the re-established native vegetation on large portions of the drawdown zone.

Over the latter half of the 1990's, there were anecdotal reports of ecological and social benefits from the revegetated drawdown zone (often referred to as the Revelstoke wetlands), including increased wildlife usage, improved trout fishing, and a high level of associated recreational use.

In 1998, BC Hydro initiated a project to evaluate the potential benefits associated with the new wetland area (Map 1). A team with expertise in revegetation and ecology was assembled to design and undertake studies of environmental benefits associated with revegetation of the drawdown zone to control dust. Initially focused on the quantification of the vegetation benefits to the local fishery, and possibly to overall fish habitat within Arrow Reservoir, additional studies addressing bird usage and recreational activities were added later. The individual studies were defined in a series of workshops attended by the multidisciplinary team.

Initial funding for the project was obtained from Fisheries Renewal BC. In 1999 BC Hydro introduced the Strategic Environmental Initiatives Program (SEIP) which was designed to fund innovative environmental and social projects related to BC Hydro's business. SEIP funding was obtained for three years of the project.

1.1 Project Goals

The following goals provided overall direction for the project:

Project Goals

- To identify the benefits of reservoir shoreline revegetation to fish, wildlife and recreational users.

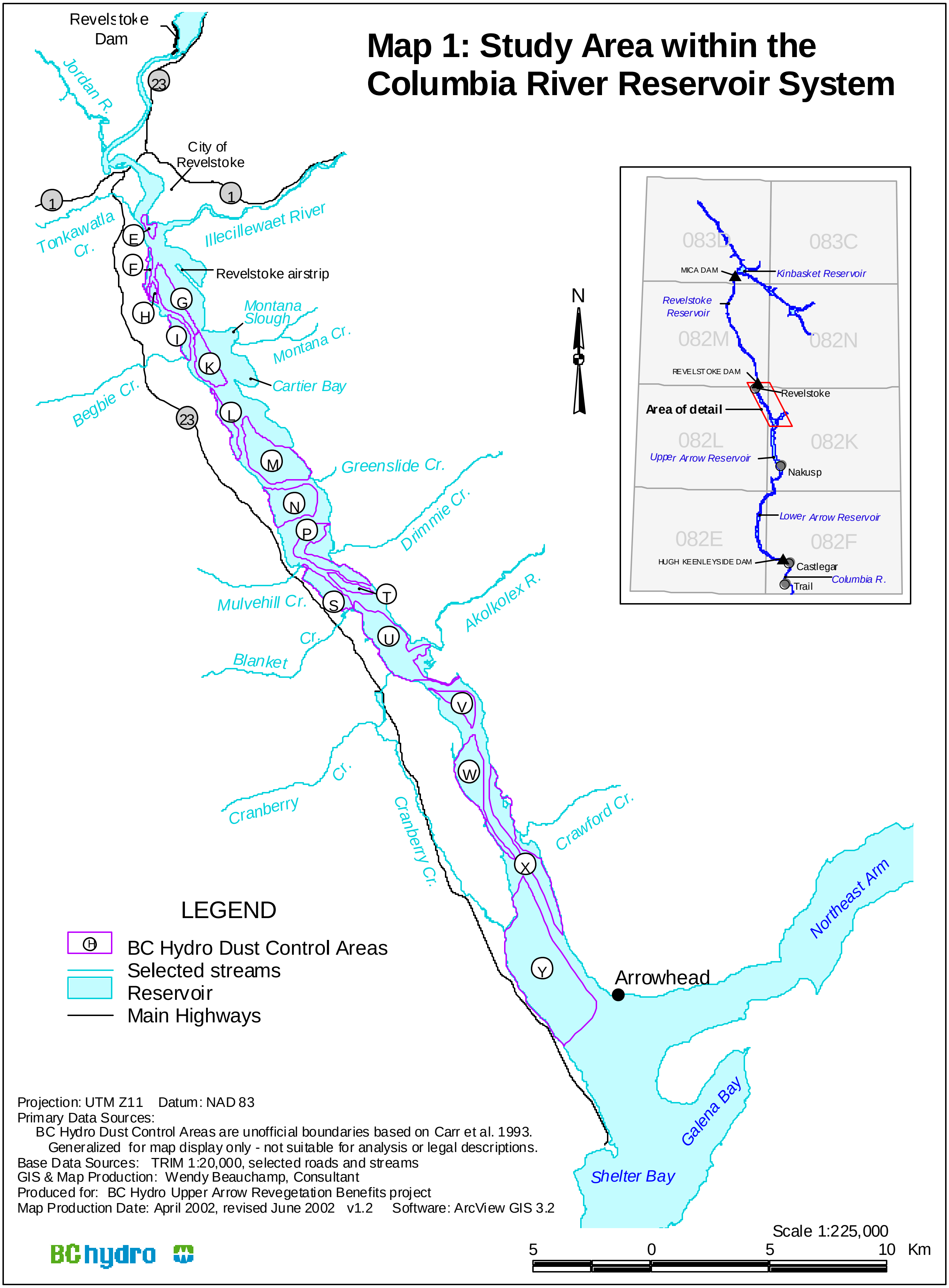
- To identify data gaps and information requirements to improve our understanding of relationships between water levels and plant growth and the wildlife use of these habitats within reservoirs. (Note: while this was not an original goal of the project, it became apparent that this was an important component of the project as it evolved).

- To provide recommendations on designing a long-term vegetation monitoring design on the treated portions of the drawdown zone that will also be applicable to other reservoirs.

- To communicate the results of the shoreline revegetation project internally to BC Hydro staff so that lessons learned may be extended to other reservoirs and externally to the communities, other government agencies and public in the Upper Arrow Reservoir region.

This report presents an overview of the project. It includes a synthesis of each of the component studies that were undertaken in support of the overall project goals.

Map 1: Study Area within the Columbia River Reservoir System



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993.
Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources: TRIM 1:20,000, selected roads and streams
GIS & Map Production: Wendy Beauchamp, Consultant
Produced for: BC Hydro Upper Arrow Revegetation Benefits project
Map Production Date: April 2002, revised June 2002 v1.2 Software: ArcView GIS 3.2

1.2 Project Team

The project team was comprised of BC Hydro staff, Contractors and Advisors. Ed Hill, Senior Environmental Coordinator, BC Hydro, managed the project. BC Hydro task managers included Wayne Duval (Water Use Planning) and Mark Johnston (Power Supply - Environment). BC Hydro technical advisors included: Karen Bray, Brian Gadbois, Paul Higgins, Carol Lamont, Wayne Sakamoto, Grietje Van Dijk, Sandra Wilson and Serge Zoritch. External advisors included Ken Ashley, Steve Macfarlane, Ross Neuman, Dan Sneep, Carl Walters and Guy Woods. Michael McPhee, Quadra Planning Consultants Ltd, served as project coordinator for the second half of the project.

1.3 Component Studies

The project involved the following components and reports.

Components	Reports
Vegetation and Soils Analyses and Vegetation Mapping	AIM Ecological Consultants Ltd., Eco-Logic Ltd. and Carr Environmental Consultants, *Vegetation Benefits To Fish: A Literature Review*. April 2000. AIM Ecological Consultants Ltd. and CARR Environmental Consultants, *Summary Report on Vegetation and Soil Analyses for the 1999 Pilot Study, Revelstoke Reach-Upper Arrow Reservoir*. May 2000 CARR Environmental Consultants and AIM Ecological Consultants Ltd. *Quantification of Vegetation Inputs to Revelstoke Reach, Summary of 2000 Field Program – Vegetation and Soil Analyses*. July 2002. CARR Environmental Consultants and AIM Ecological Consultants Ltd. *Synthesis of Vegetation and Soil Studies For Revelstoke Reach - Upper Arrow Reservoir.* May 2002. Moody, Anne, AIM Ecological Consultants Ltd. *Vegetation Mapping (1968-2000) of Dust Control Treatment Areas, Revelstoke Reach - Upper Arrow Reservoir*, March 2002 Moody, Anne, AIM Ecological Consultants Ltd. *Long-Term Monitoring of Vegetation Expansion and Trials in the Dust Control Treatment Areas of Revelstoke Reach - Upper Arrow Reservoir*. May 2002.

Components	Reports
Aquatic	Perrin, C.J., Limnotek Research and Development Inc., Golder Associates (RL&L Ltd.) and Eco-Logic Ltd. *Biofilm, Invertebrate and Fish Communities Associated With Vegetation Strata in the Drawdown Zone of the Arrow Lake Reservoir. Final Report.* March 2002.
Wildlife	Jarvis, Janice and John G. Woods. *Waterbirds of the Revelstoke Reach Wetlands, Upper Arrow Reservoir, Revelstoke*, *British Columbia, Canada*. June 2001. Jarvis, Janice. *Columbia River-Revelstoke Migration Monitoring Station Final Banding Report For 2001.* 2002. Boulanger, John, John G. Woods and Janice Jarvis. *Songbird Use of Four Floodplain Vegetation Types in the Revelstoke Reach, Upper Arrow Reservoir, British Columbia, Canada* April 2002.
Ecological Modelling	Korman, Josh. *Simulating the Response of Aquatic and Riparian Productivity to Reservoir Operations: Description of the Vegetation and Littoral Components of BC Hydro's Integrated Response Model (IRM).* December 2002.
Recreation	Pedersen, Marc. *Upper Arrow Seeding and Recreation Study*. BC Hydro Research Services, August 2001. McPhee, Michael W. *Group and Organized Recreation Activities in the Upper Arrow Reservoir Drawdown Zone.* March 2002
Mapping and GIS	Beauchamp, Wendy, GIS contractor, BC Hydro. Project maps, GIS and GPS (See Appendix 1)

1.4 Report Organization

This report summarizes the key findings for the main components of the study, including vegetation and soils analysis, aquatics, wildlife, ecological model and aesthetics and recreation. The sources of material for this study are the detailed reports as outlined in the table above. Readers are encouraged to consult the individual studies for more detailed analyses. No attempt has been made in this overview report to interpret findings or results of the authors of these reports. Rather, the objective in this report is a compilation of results.

1.5 Acknowledgements

This project would not have been possible without funding support provided by the Strategic Environmental Initiatives Program of BC Hydro and Fisheries Renewal BC.

Many people were responsible for seeing this project through to completion. It was managed by Ed Hill, Senior Environmental Coordinator, BC Hydro. Ed was assisted by Michael McPhee, Quadra Planning Consultants Ltd. Wayne Duval, Environment Coordinator, Columbia River Water Use Planning oversaw the completion of the aquatic and ecological modeling components and provided ongoing critical analyses and comments throughout the project. Wendy Beauchamp was responsible for generating the maps and other GIS and GPS field products. Brian Gadbois, BC Hydro, Revelstoke, provided critical comments and other logistical support to the project and to project contractors. Mark Johnston, BC Hydro (retired) also provided comments and ongoing support. Jack Matches, BC Hydro, oversaw the production of the Digital Elevation Model (DEM) and orthophotography.

We are indebted to the following researchers who undertook components of the project:

Anne Moody, Will Carr, Chris Perrin, John Stockner, Josh Korman, John Woods, Janice Jarvis, John Boulanger, Marie Gallagher and Michael McPhee. Marc Pedersen, BC Hydro Research Services directed the recreation survey of Revelstoke residents.

We would like to dedicate this project in memory of Dr. Wayne Duval.

2.0 Synthesis of Vegetation and Soil Studies for Revelstoke Reach - Upper Arrow Reservoir

Will Carr, CARR Environmental Consultants and Anne Moody, AIM Ecological Consultants Ltd.

2.1 Background

Since the late 1980's, significant portions of the Revelstoke Reach of Arrow Reservoir (often referred to as Upper Arrow Reservoir) have been repeatedly seeded with fall rye for wind erosion control and dust abatement. Initially, only 200-350 ha of identified dust source area was seeded with fall rye. However this program was expanded to affect over 1000 ha in 1991. The seeding has continued for dust control annually, with the program modified each year based on projected water levels, shifts in dust source locations, and the encroachment/establishment of native vegetation on previously seeded areas. The shift in treatment areas as a result of native vegetation colonization has allowed the annual seeding program to address other identified dust source areas while leaving wind erosion control to the re-established native vegetation on large portions of the drawdown zone.

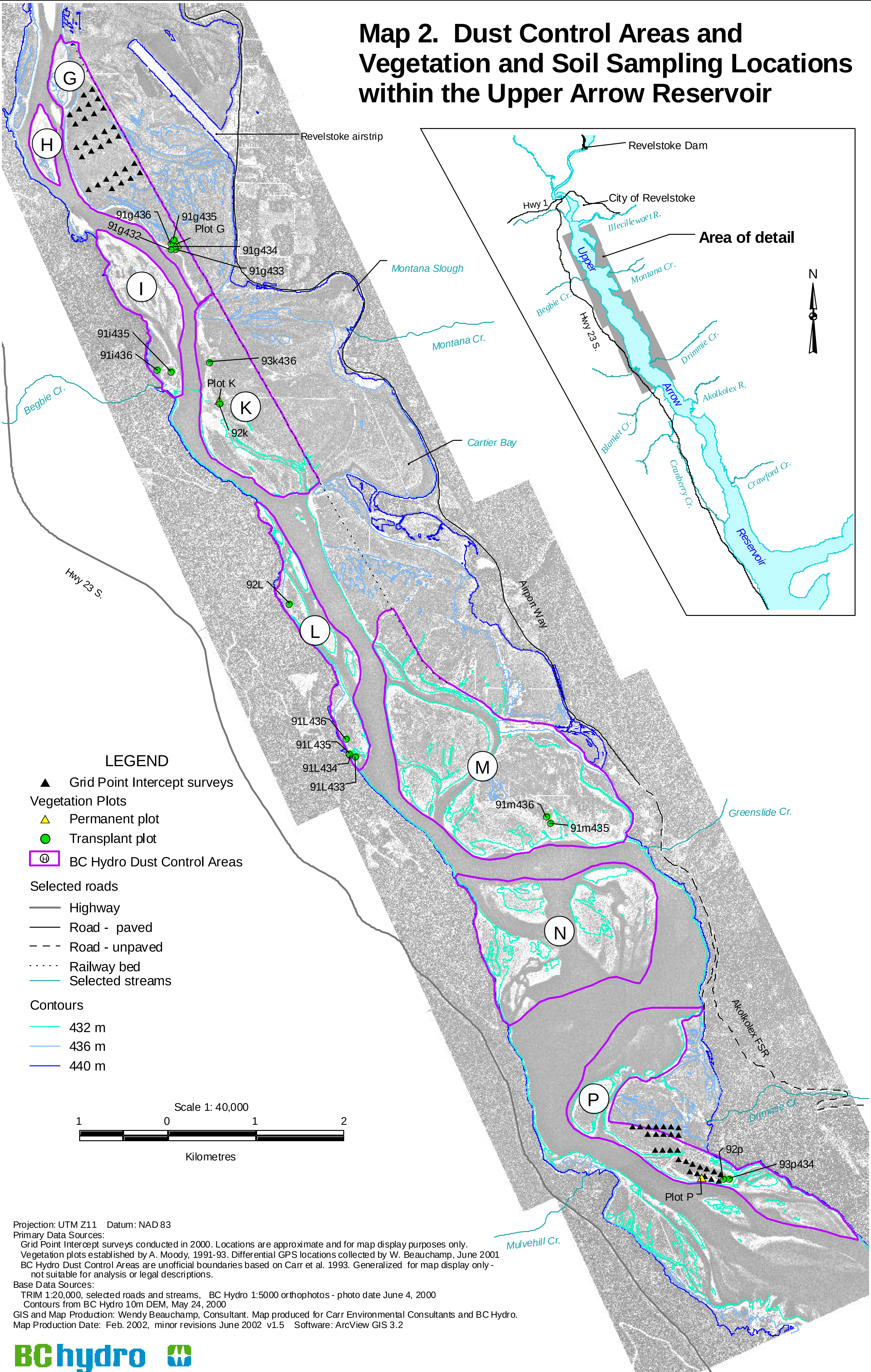
Past, informal monitoring of the vegetation establishment within Upper Arrow has indicated that in addition to the annual seeded fall rye, three major perennial vegetation communities have evolved within the treated (i.e. seeded) portions of the reservoir:

1. Sedge dominated communities, including other wetland species (extending from 433 to 436 m)
2. Reed canary grass community, including an understory of wetland species (extending from 434 to 436+m)
3. Horsetail dominated communities (occurring primarily at 435+m)

Over the latter half of the 1990's, there had been anecdotal reports of ecological and social benefits from the revegetated drawdown zone (often referred to as the Revelstoke wetlands), including increased wildlife usage, improved trout fishing, and a high level of associated recreational use. In 1999, BC Hydro initiated an evaluation of the potential benefits associated with the new wetland area under the Strategic Environmental Initiatives Program (SEIP). Initially focused on the quantification of the vegetation benefits to the local fishery, and possibly to overall fish habitat within Arrow Reservoir, additional studies addressing bird usage and recreational activities were added in 2001.

An objective of the BC Hydro Strategic Environmental Initiatives Program: Evaluation of Ancillary Benefits of Reservoir Drawdown Zone Revegetation is quantification of the potential contribution to aquatic and terrestrial resource values of the vegetation community that has established as a result of the Arrow Dust Control Program (Map 2). The development of extensive areas of vegetation within the reservoir has the potential to affect both the aquatic and

Map 2. Dust Control Areas and Vegetation and Soil Sampling Locations within the Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Grid Point Intercept surveys conducted in 2000. Locations are approximate and for map display purposes only.
Vegetation plots established by A. Moody, 1991-93. Differential GPS locations collected by W. Beauchamp, June 2001
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993. Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams, BC Hydro 1:5000 orthophotos - photo date June 4, 2000
Contours from BC Hydro 10m DEM, May 24, 2000
GIS and Map Production: Wendy Beauchamp, Consultant. Map produced for Carr Environmental Consultants and BC Hydro.
Map Production Date: Feb. 2002, minor revisions June 2002 v1.5 Software: ArcView GIS 3.2

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terrestrial phases of the drawdown ecosystem by providing structural habitat (shelter and cover) and organic (food web) inputs that can be utilized by a variety of organisms. A key step in understanding the magnitude and importance of these ecosystem inputs and potential linkages to both aquatic and terrestrial productivity is quantifying the inherent quality of the new wetland community that has developed over the past decade, the goal of the Reservoir Vegetation and Soil Studies. The distribution and development of wetland communities as influenced by reservoir elevation (an indication of the effect of annual inundation) and performance of individual plant species (including biomass production and nutrient content) are important metrics in assessing the ecosystem value of the new wetlands, and the primary tasks in the Reservoir Vegetation and Soil Studies component. Quantification of these inputs will contribute to the development of an ecosystem model (Korman, 2002), which has been put forward in a theoretical stage, to help define the linkage between reservoir vegetation and habitat values and to allow for extrapolation to other reservoirs.

2.2 Objectives

Three major objectives have been identified within the Reservoir Vegetation Studies component of the Upper Arrow Reservoir Evaluation of Ancillary Benefits of Reservoir Drawdown Zone Revegetation study:

1. To establish a long-term monitoring design on the treated (seeded for dust control) portion of the drawdown zone in Revelstoke Reach of the Upper Arrow Reservoir
2. To quantify the biomass contributions of vegetation in the three major plant communities that have developed as a result of the dust control seeding program; including organic inputs, nutrients (nitrogen and phosphorus), and carbon
3. To develop tested data inputs for the RESVEG ecosystem model for linking vegetation to reservoir habitat values (Korman, 2002)

To help accomplish these objectives, a three-year study was undertaken with the following tasks:

- To quantify the distribution of vegetation and evaluate the colonization rates of native species within the revegetated areas in the Revelstoke Reach
- To quantify biomass, nutrients (N, P, & K) and carbon levels of the plant communities to determine the potential contribution of vegetation to the surrounding ecosystems
- To develop a system for a long term monitoring program that examines relative abundance, species composition, and biomass within the study area

The field study was a cooperative program between CARR Environmental Consultants, AIM Ecological Consultants Ltd., and Pacific Soil Analysis Ltd. The first two years of the program, 1999 and 2000, focused on the sampling of above-ground and below-ground biomass of the permanent vegetation cover for quantification of biomass production (dry-weight/unit area), nutrient (N, P, and K) content and carbon distribution. All field sampling was stratified into one-meter elevation bands over the range 434 m to 437+ m to ascertain the influence of depth and time of inundation on vegetation performance. The contribution of soil to the overall carbon pool, reflecting plant detritus inputs over the years, was also estimated. The third year of the program focused on the integration of biomass, nutrient and carbon distribution data from the 2000 field sampling program with vegetation mapping and a new digital terrain model to provide estimates of biomass and nutrient production for the permanent vegetation throughout the entire recolonized area in Revelstoke Reach.

This current report is a summary synthesis of the field program and airphoto assessment, and provides an overview of the three-year program. Some data has been selected for presentation in this report to show key effects or trends. Details of the program activities for each year and results of the analysis can be found in the following individual reports:

- Summary Of 1999 Vegetation and Soil Analyses (AIM and CARR, 2000)
- Summary Of 2000 Vegetation and Soil Analyses (CARR and AIM, 2002)
- Vegetation Mapping (1968 - 2000) of Dust Control Treatment Areas - Revelstoke Reach - Upper Arrow Reservoir (Moody, 2002)

2.3 Limitations

Over the three-year study, as well as the first four years of the Dust Control Program (1990-1994), the annual variability in water management regime for the Upper Arrow Reservoir has been the most problematic issue to address within the context of field studies in the Revelstoke Reach. From year to year, the variability of reservoir elevation through the growing season can be as great as 15 m on a given date. This directly influences the growth, maturity and production of plant biomass at a given sampling date, as well as having a carryover influence on the following year's plant performance which is a function of carbon and nutrient reserves accumulated in the previous year(s). The data collected on a given date from year to year are not directly comparable, but serve as a comparative index of plant growth and performance given the current (and past) water levels.

Sampling throughout the growing season, until inundation, could provide data that is more comparable from year to year, however given the high degree of variability in annual water regime (and low level of predictability from a plant growth perspective) it is not warranted. The focus should be on major vegetation trends over time, something that can be accomplished through the airphoto mapping, with periodic assessment of biomass, nutrient and carbon parameters to help quantify ecosystem changes.

2.4 Overview Of Results

2.4.1 Key field study results

The field studies undertaken under this project have covered a wide range of vegetation and soil related parameters, initially from a scoping perspective with some more focused studies in year two. While the detail of the field studies can be found in the baseline data reports (AIM and CARR 2000, CARR and AIM 2002), the key results relating vegetation development, production and associated ecosystem benefits include:

- species composition of the permanent vegetation community
- plant biomass production and the effect of reservoir elevation and inundation
- plant and soil carbon pool development

The additional data collected during the field study, particularly the nutrient (N, P, and K) distribution within the specific plant species, did not demonstrate very strong trends at the limited scale of sampling and is not discussed in this report. However it could be of significance when combined with more detailed studies in the future to address specific nutrient accumulation and availability issues.

2.4.2 Carbon pool

The carbon pool is an integration of the organic (live and detritus) inputs from the vegetation, its distribution, accumulation and incorporation into the soil profile. Species and elevation have been shown to play a role in the performance of the vegetation throughout the study areas, and this continues with organic carbon distribution and accumulation. The biomass components were converted to carbon using the determined value of the shoots and roots being 45% carbon based on the tissue analysis from 1999. (CARR and AIM, 2002).

The net carbon accumulation, i.e. total carbon pool minus control carbon content, is approximately 35 tC/ha in less than 10 years. This is a level that will increase over time as the vegetation cover continues to build root and soil carbon reserves until reaching a steady state maximum for this unique ecosystem. Aside from the dust control, recreation, fish and wildlife habitat enhancement, and other benefits of reservoir revegetation, further investigation into the potential for carbon sequestration and greenhouse gas carbon off-sets appears warranted.

2.4.3 Integration of airphoto mapping and DTM development with field biomass data

In 2000/2001, AIM Ecological Consultants Ltd. undertook a vegetation mapping program to quantify the distribution of different vegetation types within the dust control study area using historical and current aerial photographs. The results from the mapping using photos from 1968 (pre-impoundment), 1977, 1991 (start of Upper Arrow Dust Control Program), and 2000 were transferred to new orthographic map sheets for the Revelstoke Reach and integrated into BC Hydro’s GIS-based digital terrain map (DTM) for the dust treatment area (AIM, 2002). (See Maps 3-6). This approach allowed for a historical perspective of vegetation development in the study area and an evaluation of the role of intervention (seeding and planting) in promoting vegetation establishment within the reservoir. Stratification of the map units into vegetation types and growth performance categories (based on plant density and vigour) can also be combined with field-based estimates of biomass production and nutrient content to allow for extrapolation of the field data to the entire study area.

2.4.4 Vegetation change over time

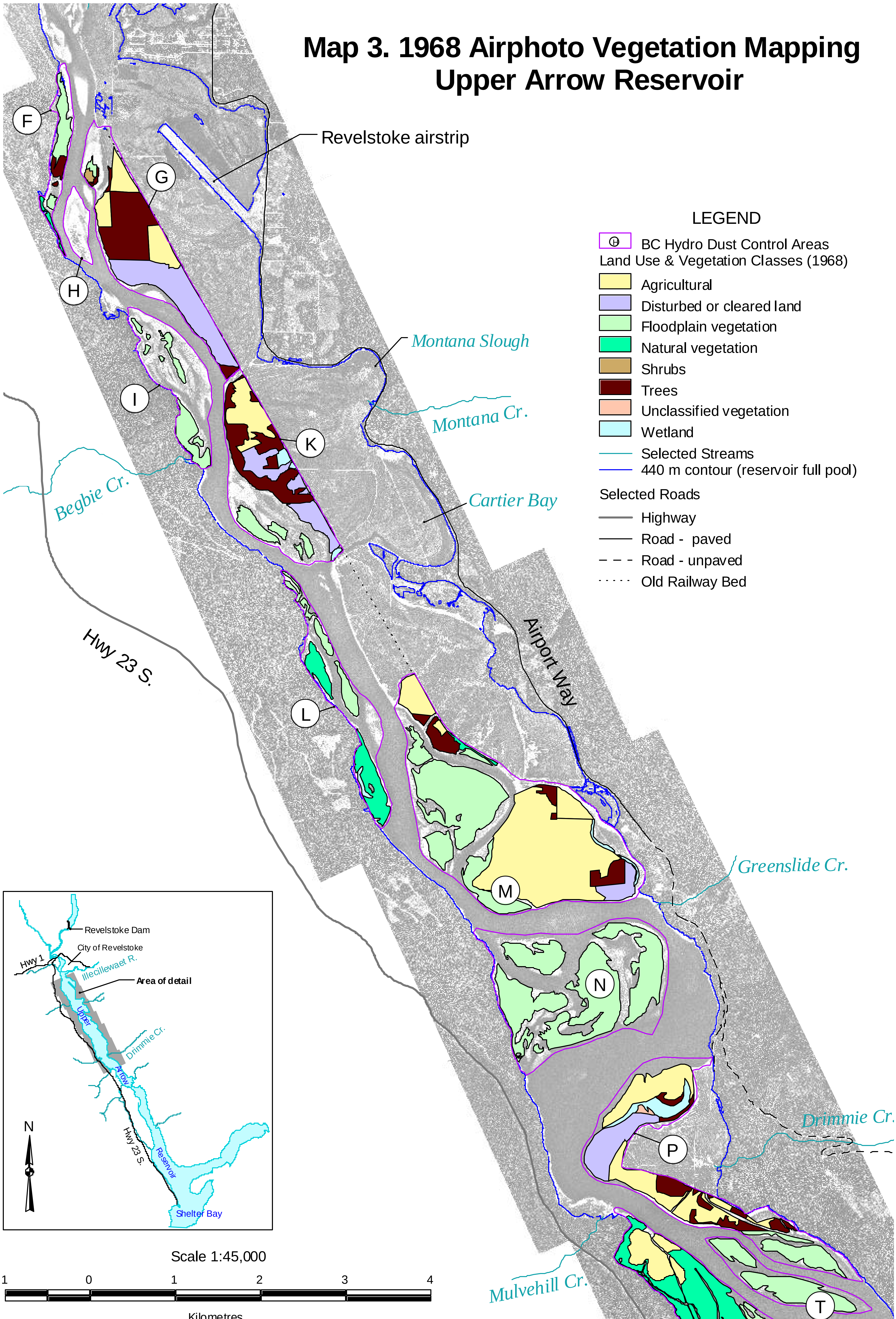
Overall, in 2000, perennial vegetation occupied 498.7 ha in areas F through T (Table 1). This represents a large decline from the pre-impoundment area of 1,046.1 ha.

Table 1: Summary of Vegetated Areas (ha) by Treatment Area and Year

Dust Control Area	1968	1977	1991	2000
F	18.6	1.7	14.1	14.6
G	123.0	29.7	56.2	117.3
H	0.0	0.0	0.0	3.9
I	19.7	0.6	7.1	14.1
K	102.9	19.0	24.2	100.3
L	42.4	1.9	1.6	20.0
M	301.8	32.9	49.4	150.6
N	138.3	0.0	0.0	3.7
P	146.0	9.0	7.4	44.4
S	116.7	25.1	10.1	29.8
T	36.8	0.0	0.0	0.0
Total	**1,046.1**	**120.1**	**170.0**	**498.7**

The decline in vegetation cover was very dramatic between 1968 and 1977. By 1977, only 12% of the pre-impoundment area included in the mapping exercise remained vegetated. Very little change (50 ha) was observed in the total amount of vegetated area between 1977 (120 ha) and 1991 (170 ha). Between 1991 and 2000, perennial wetland vegetation increased a total of 329 ha in areas associated with the annual seeding program. The largest increase occurred at area "M" with over 100 ha gained since 1991. Next were K (76 ha), G (61 ha), and P (37 ha). From an ecological perspective, the increase in permanent wetland area within the formerly barren drawdown zone represents a significant enhancement of habitat values/contributions to the terrestrial and aquatic phases of the reservoir.

Map 3. 1968 Airphoto Vegetation Mapping Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Vegetated areas interpreted from BC Hydro airphotos (photo date May 9, 1968, 1:30,000, black & white)
Airphoto interpretation: Anne Moody (AIM Ecological Consultants, Ltd.)
Digitizing: Ken Bocker & Gary Belcourt, BC Hydro. GIS processing: Wendy Beauchamp, GIS consultant.
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993.
Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams. BC Hydro 1:5000 orthophotos: photo date June 4, 2000
Contours from BC Hydro 10m DEM: May 24, 2000
Map Production: Wendy Beauchamp, Consultant. Map produced for AIM Ecological Consultants Ltd. and BC Hydro.
Map Production Date: April 2002, modified June 2002 v1.3 Software: ArcView 3.2

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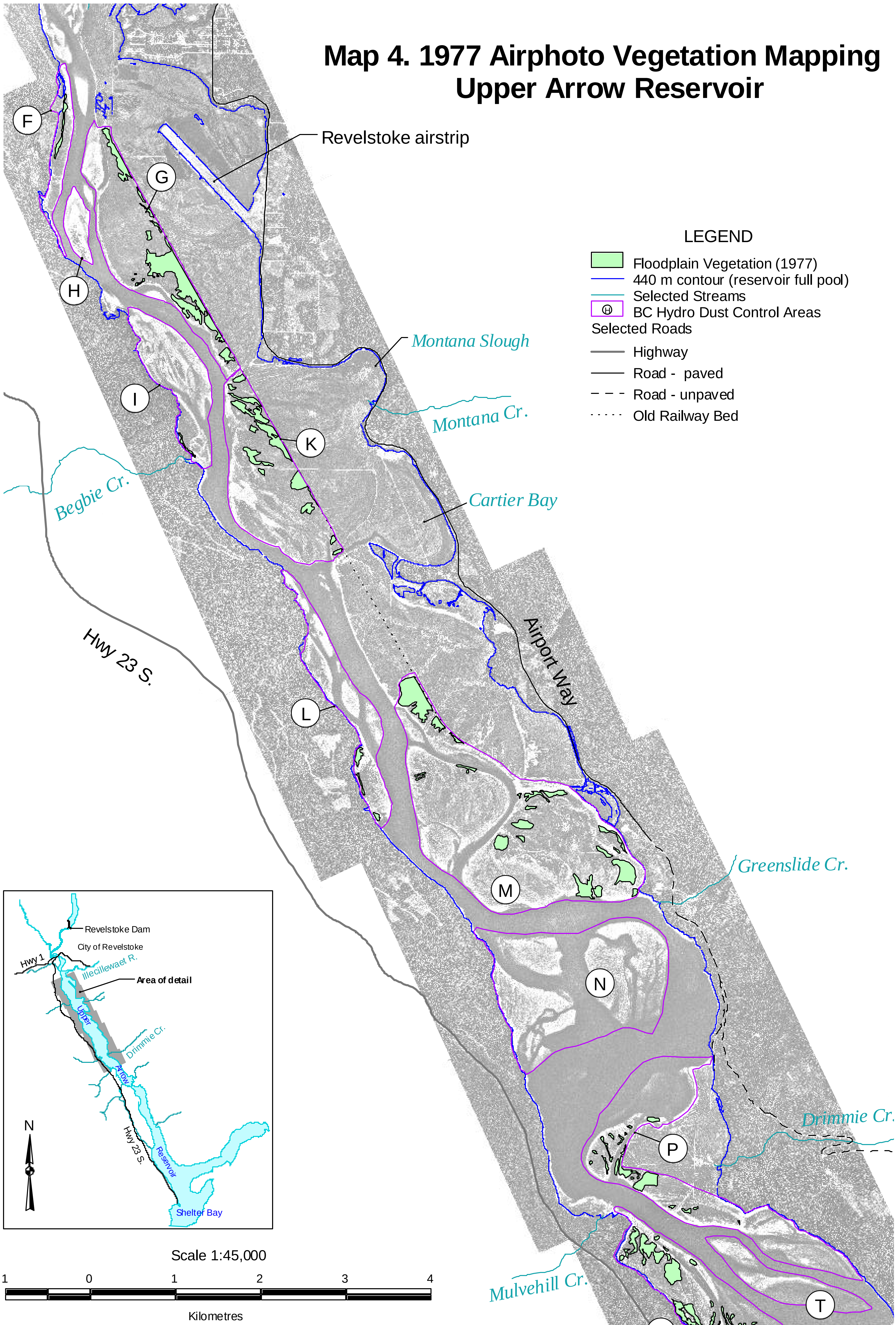
Map 4. 1977 Airphoto Vegetation Mapping Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Vegetated areas interpreted from BC Hydro airphotos (photo date Aug. 7, 1977, 1:20,000, colour)
Airphoto interpretation: Anne Moody (AIM Ecological Consultants, Ltd.)
Digitizing: Ken Bocker & Gary Belcourt, BC Hydro. GIS processing: Wendy Beauchamp, GIS consultant.
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993.
Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams. BC Hydro 1:5000 orthophotos: photo date June 4, 2000
Contours from BC Hydro 10m DEM: May 24, 2000
Map Production: Wendy Beauchamp, Consultant. Map produced for AIM Ecological Consultants Ltd. and BC Hydro.
Map Production Date: April 2002 v1.3, modifiied June 2002 Software: ArcView 3.2

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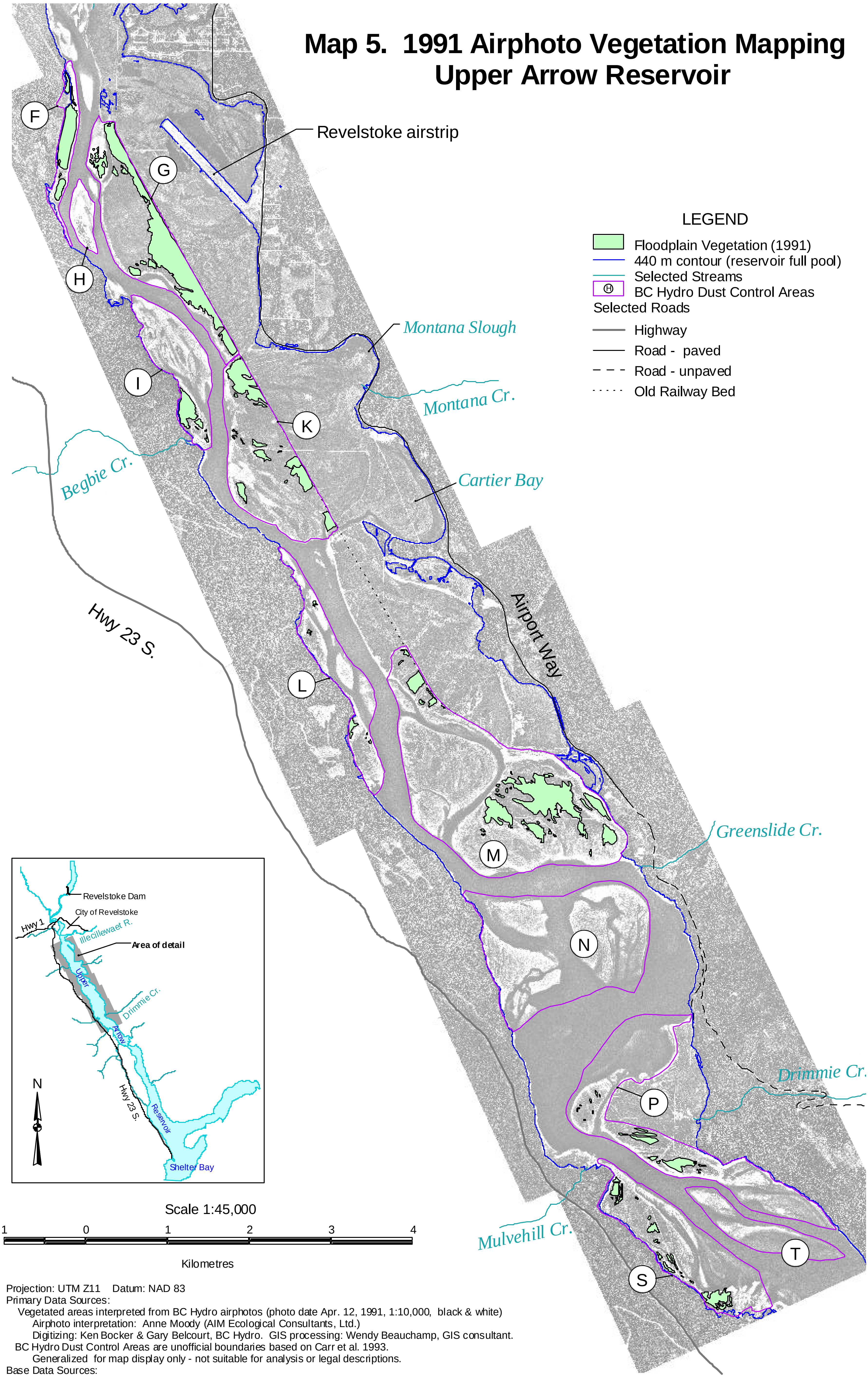
Map 5. 1991 Airphoto Vegetation Mapping
Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Vegetated areas interpreted from BC Hydro airphotos (photo date Apr. 12, 1991, 1:10,000, black & white)
Airphoto interpretation: Anne Moody (AIM Ecological Consultants, Ltd.)
Digitizing: Ken Bocker & Gary Belcourt, BC Hydro. GIS processing: Wendy Beauchamp, GIS consultant.
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993.
Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams. BC Hydro 1:5000 orthophotos: photo date June 4, 2000
Contours from BC Hydro 10m DEM: May 24, 2000
Map Production: Wendy Beauchamp, Consultant. Map produced for AIM Ecological Consultants Ltd. and BC Hydro.
Map Production Date: April 2002 v1.2, revised June 2002 Software: ArcView 3.2

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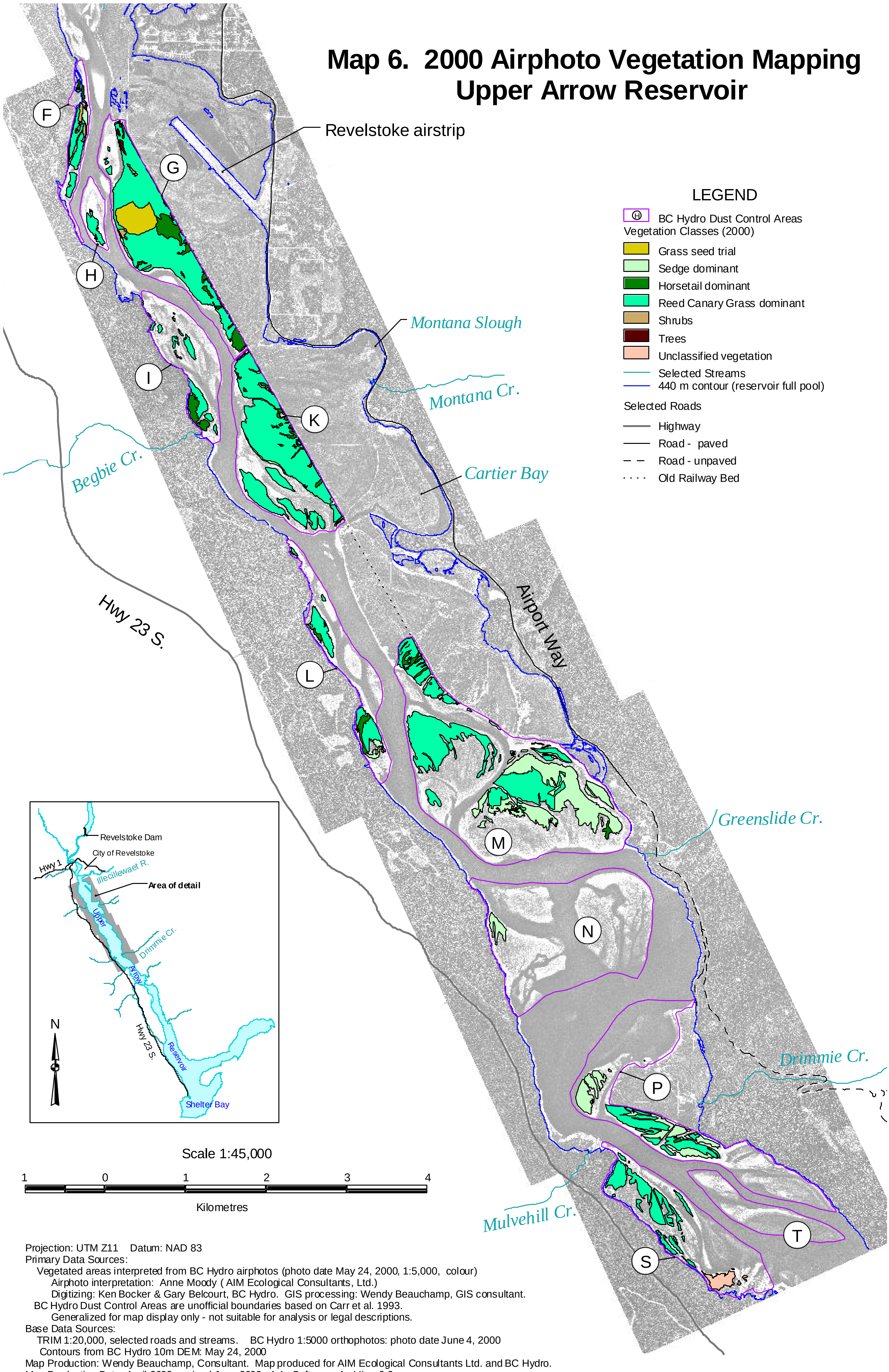
Map 6. 2000 Airphoto Vegetation Mapping
Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Vegetated areas interpreted from BC Hydro airphotos (photo date May 24, 2000, 1:5,000, colour)
Airphoto interpretation: Anne Moody (AIM Ecological Consultants, Ltd.)
Digitizing: Ken Bocker & Gary Belcourt, BC Hydro. GIS processing: Wendy Beauchamp, GIS consultant.
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993.
Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams. BC Hydro 1:5000 orthophotos: photo date June 4, 2000
Contours from BC Hydro 10m DEM: May 24, 2000
Map Production: Wendy Beauchamp, Consultant. Map produced for AIM Ecological Consultants Ltd. and BC Hydro.
Map Production Date: April 2002, revised June 2002 v1.4 Software: ArcView 3.2

BChydro

2.4.5 Vegetation development as a function of reservoir elevation

Subsequent integration of the 2000/01 mapping with the GIS-based DTM developed by BC Hydro has allowed for an analysis of the influence of reservoir elevation on the distribution and development of plant communities (stratified by dominant species) within the new wetland community in Revelstoke Reach. Although the horsetail, reed canarygrass and sedge communities occur as low as 431 m, the level of development is minimal until 434 m (Table 2). Between 434 m and 440 m, each of the plant communities exhibits a different development pattern as a function of elevation, reflecting its tolerance to inundation and vegetation competition.

Table 2: Plant community establishment as a function of reservoir elevation

Elevation	Horsetail	Reed Canarygrass	Sedges	Shrubs
431 m		<1 ha	<1 ha	
432 m		<1 ha	1.9 ha	
433 m	<1 ha	7.3 ha	7.0 ha	
434 m	1.9 ha	67.3 ha	23.6 ha	
435 m	9.4 ha	114.6 ha	36.2 ha	
436 m	8.7 ha	65.5 ha	19.1 ha	
437 m	5.2 ha	36.7 ha	2.2 ha	<1 ha
438 m	4.7 ha	65.2 ha	1.3 ha	3.2 ha
439 m	<1 ha	4.1 ha	<1 ha	<1 ha
440+ m		<1 ha	<1 ha	<1 ha
Totals	**30.3 ha**	**361.3 ha**	**91.8 ha**	**3.5 ha**

Note: Data in this table were developed specifically for this synthesis report using the 2001 DTM and mapping.

2.5 References

AIM Ecological Consultants Ltd. and CARR Environmental Consultants. 2000. Summary Report on Vegetation and Soil Analyses for the 1999 Pilot Study.

Boulanger, John, John G. Woods and Janice Jarvis. Songbird Use of Four Floodplain Vegetation Types in the Revelstoke Reach, Upper Arrow Reservoir, British Columbia, Canada. April 2002.

CARR Environmental Consultants and AIM Ecological Consultants Ltd. 2002. Quantification of Vegetation Inputs to Revelstoke Reach, Summary of 2000 Field Program – Vegetation and Soil Analyses.

Korman, J. 2002. Simulating the Response of Aquatic and Riparian Productivity to Reservoir Operations: Description of the Vegetation and Littoral Components of BC Hydro's Integrated Response Model (IRM).

Moody, A.I. 1998. BC Hydro Upper Arrow Dust Control Program: Wetland Plant Trials, Monitoring Results 1991-1997.

Moody, Anne I. 2002. AIM Ecological Consultants Ltd. Vegetation Mapping (1968 - 2000) of Dust Control Treatment Areas - Revelstoke Reach - Upper Arrow Reservoir.

2.6 Vegetation Benefits to Fish – A Literature Review

AIM Ecological Consultants Ltd., Eco-Logic Ltd., and CARR Environmental Consultants. *Vegetation Benefits to Fish: a Literature Review*. April, 2000.

AIM Ecological Consultants Ltd. in association with Eco-Logic Ltd., and Carr Environmental Consultants undertook a literature review to document previous studies that would:

- quantify the role of vegetation in aquatic ecosystem productivity, in particular fish;
- identify the relationship between aquatic vegetative growth and decomposition to fish productivity, and other contributors to the food web; and,
- focus on reservoirs, but include relevant information from lake and other aquatic environments.

Key Findings

- Relevant reservoir, fish and vegetation studies were reviewed from a broad north temperate perspective, with specific reference to the B.C. situation whenever possible. General principles, as they related to the "potential" benefits of vegetation to fish were included from studies not directly applicable to B.C. Much of the existing literature was not directly related to the climatic conditions, native plant species or fish populations existing in B.C. Reservoirs have received limited ecological and limnological attention compared to natural waterbodies. Very little relevant research has been conducted in Canadian reservoirs or wetlands.

- Reservoirs generally have a scarcity of littoral vegetation largely because of annual water level fluctuations. The resulting lack of cover from aquatic vegetation may increase predation on small fish. These fluctuations may also result in reduced littoral productivity and decreased growth rates in fish.

- Aquatic invertebrates provide the critical ecosystem linkages in energy, nutrient and carbon flows between primary producers, microbial assemblages and higher consumers such as fish and waterfowl. Aquatic plants have been shown to positively alter conditions of water velocity, substrate, detritus (food) availability, etc. for invertebrates. Aquatic invertebrate populations are significantly higher in vegetated sites compared to non-vegetated sites.

Information Needs

Despite several decades of scientific investigations into the structural and functional roles of vegetation for fish, there is a general consensus that even those freshwater ecosystems that have received the most attention (i.e. shallow eutrophic lakes) are poorly understood. The lack of scientific knowledge and understanding is even more pronounced for reservoirs particularly in western North America.

Aquatic and emergent vascular plants are recognized as important producers of large volumes of organic material and may function as exporters, transformers or repositories of nutrients in the aquatic ecosystem. These functions vary tremendously according to local environmental and biological factors. Site and species specific information is essential for an understanding of the contribution of the primary producers to the aquatic foodweb.

The epifloral and epifaunal assemblages associated with macrophytes are key elements in nutrient and energy transfer within aquatic ecosystems. The importance of this microbial loop to trophic cycling has only just begun to be appreciated. Macroinvertebrates form the critical linkage between periphyton grazers and fish. Aquatic vegetation provides structural habitat complexity for invertebrates and juvenile fish as well as rich feeding grounds for both. To date some understanding has been gained about individual trophic levels and to a limited extent, some of the linkages and interactions between adjacent trophic levels. What is missing, however, is a deeper understanding at the ecosystem level of the intricate responses, interactions and interdependencies of freshwater biota.

Reservoirs are characterized by periodic water level fluctuations as water is alternately released and retained for various purposes. The potential effects of these fluctuations are greatest in the nearshore littoral zone, a zone which is generally considered to be the most productive area in natural lakes. The biotic responses of the macrophyte-periphyton-invertebrate-fish system to periodic inundation and exposure of littoral habitats are largely unknown. Similarly the potential for cascading effects from the littoral system to the pelagic system is not understood. An understanding of the complexities of biotic processes in reservoirs will lead to more effective management of multipurpose reservoir ecosystems.

3.0 Biofilm, Invertebrate and Fish Communities Associated With Vegetation Strata in the Drawdown Zone of the Upper Arrow Reservoir

Limnotek Research and Development Inc., Golder Associates (RL&L Ltd.) and Eco-Logic Ltd.

3.1 Background

An experiment was implemented in 1999 to examine the effect of submersed vegetation on the abundance and composition of periphyton, benthic invertebrates, and fish in the drawdown zone of Revelstoke Reach in the Arrow Lakes Reservoir. In this reach, vegetation communities are stratified by elevation with barren soils at lowest elevations and native mixed grasses at highest elevations. In some barren areas, fall rye is planted early in the spring each year to control dust before inundation in late spring. Survival of plant species while under water each summer is determined by time under water and characteristics of each species to tolerate submersed conditions. This report describes results of the experiment and it provides an interpretation of the findings.

3.2 Experimental Design

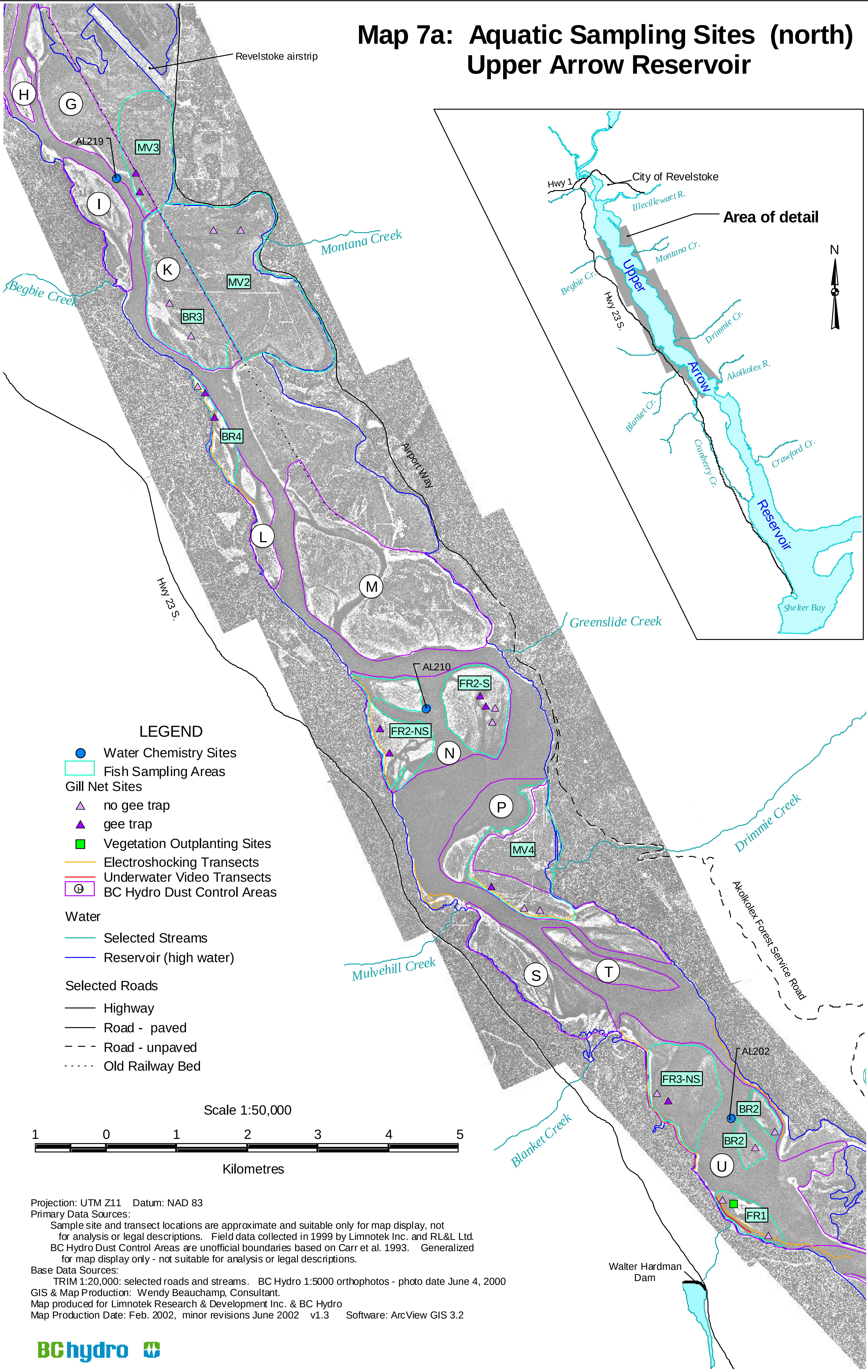
3.2.1 Periphyton and Benthic Invertebrates

An important feature of the Revelstoke Reach is that vegetation communities are stratified by elevation. The communities are largely determined by the length of time they are under water during the growing season each year. Diverse communities of native vegetation have invaded the highest elevations above 435 m. These zones are flooded for less than 150 days each year and when water reaches full pool, water depths are relatively shallow (<5 m). At the other extreme, barren sites where vegetation has not become established are at elevations less than 434 m with most close to 431 m. These zones are flooded for more than 150 days each year and water depths are mostly >8m at full pool.

This natural stratification introduced confounding between two factors, one being vegetation type and the other being elevation. Consequently, effects of vegetation type and elevation on endpoint measurements that are associated with plant substrata (e.g. invertebrate abundance or biomass) could not be separated using conventional in situ sampling techniques. Any difference in measurements of the endpoints found in grab samples collected from substrata at different elevations could only be attributed to combinations of vegetation type (the substrata of interest) and elevation. Since the objective of the study was to examine specific effects of vegetation type, alternate techniques were required.

To get around this problem, sampling of outplanted substrata containing several vegetation types at several elevation strata was laid out (Map 7). In this design, replicated samples of selected

Map 7a: Aquatic Sampling Sites (north) Upper Arrow Reservoir



Projection: UTM Z11 Datum: NAD 83

Primary Data Sources:

Sample site and transect locations are approximate and suitable only for map display, not for analysis or legal descriptions. Field data collected in 1999 by Limnotek Inc. and RL&L Ltd.

BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993. Generalized for map display only - not suitable for analysis or legal descriptions.

Base Data Sources:

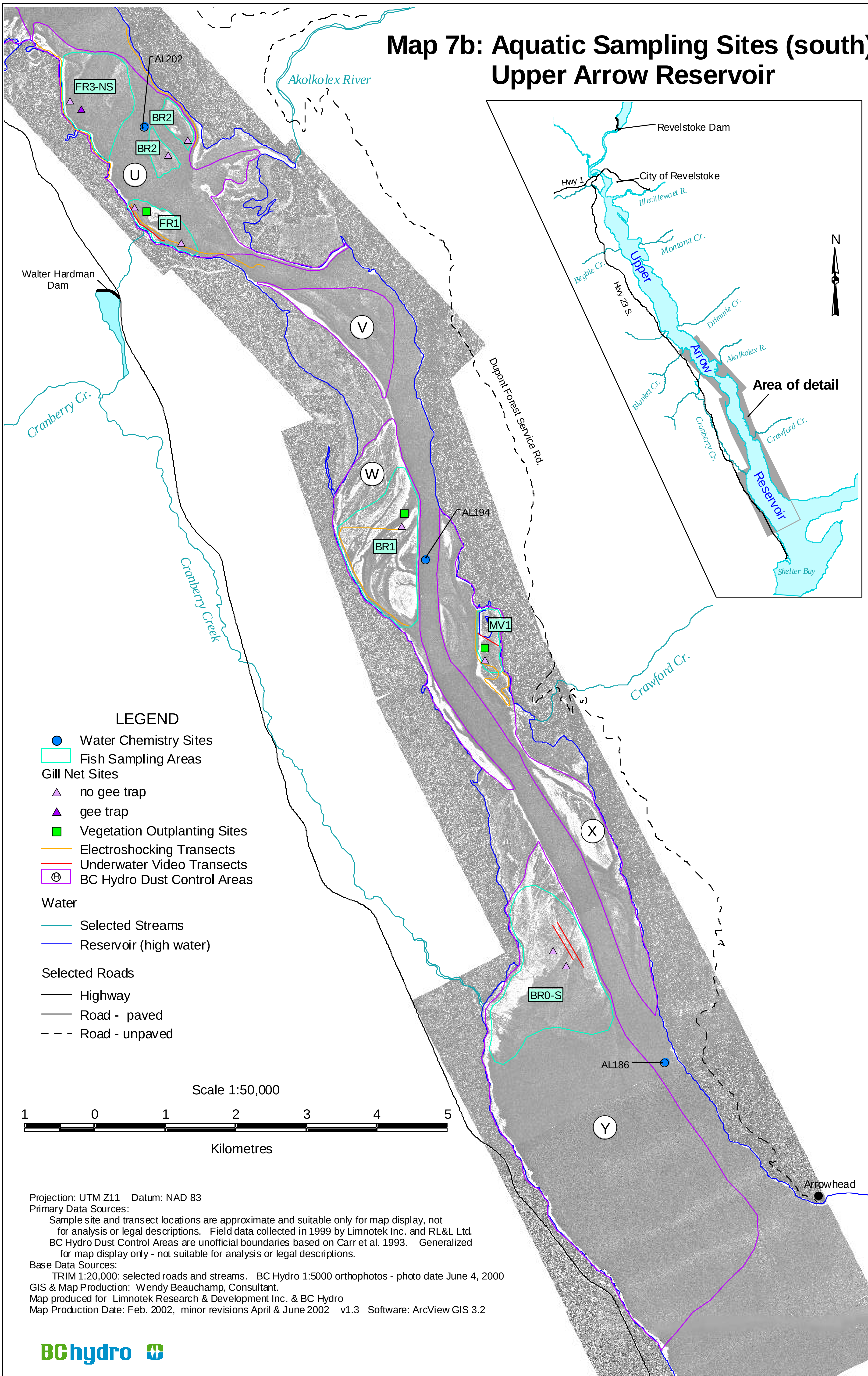
TRIM 1:20,000: selected roads and streams. BC Hydro 1:5000 orthophotos - photo date June 4, 2000

GIS & Map Production: Wendy Beauchamp, Consultant.

Map produced for Limnotek Research & Development Inc. & BC Hydro

Map Production Date: Feb. 2002, minor revisions June 2002 v1.3 Software: ArcView GIS 3.2

BC hydro



Map 7b: Aquatic Sampling Sites (south)
Upper Arrow Reservoir
Akolkolex River
AL202
FR3-NS
BR2
BR2
U
FR1
Walter Hardman
Dam
V
Cranberry Cr.
Dupont Forest Service Rd.
W
AL194
BR1
Cranberry Creek
MV1
Crawford Cr.
X
BR0-S
AL186
Y
Arrowhead
Revelstoke Dam
City of Revelstoke
Hwy 1
Illecillewaet R.
Montana Cr.
Begbie Cr.
Hwy 23 S.
Upper
Drimmie Cr.
Arrow
Akolkolex R.
Blanket Cr.
Area of detail
Cranberry Cr.
Crawford Cr.
Reservoir
Shelter Bay
N
LEGEND
Water Chemistry Sites
Fish Sampling Areas
Gill Net Sites
no gee trap
gee trap
Vegetation Outplanting Sites
Electroshocking Transects
Underwater Video Transects
BC Hydro Dust Control Areas
Water
Selected Streams
Reservoir (high water)
Selected Roads
Highway
Road - paved
Road - unpaved
Scale 1:50,000
1 0 1 2 3 4 5
Kilometres
Projection: UTM Z11 Datum: NAD 83
Primary Data Sources:
Sample site and transect locations are approximate and suitable only for map display, not for analysis or legal descriptions. Field data collected in 1999 by Limnotek Inc. and RL&L Ltd.
BC Hydro Dust Control Areas are unofficial boundaries based on Carr et al. 1993. Generalized for map display only - not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000: selected roads and streams. BC Hydro 1:5000 orthophotos - photo date June 4, 2000
GIS & Map Production: Wendy Beauchamp, Consultant.
Map produced for Limnotek Research & Development Inc. & BC Hydro
Map Production Date: Feb. 2002, minor revisions April & June 2002 v1.3 Software: ArcView GIS 3.2
BC hydro

plant species were dug up, placed in containers that allowed plant growth to continue when replanted back into the ground, and moved to selected elevation strata for removal and sampling at points in time after inundation. This process of digging up intact plants and root masses and replanting at alternate locations was called “outplanting”. At time of sampling, the containers were easily pulled from substrata using a line and winch operated from a boat, eliminating the need for conventional grab equipment. This approach allowed measurements of endpoints to be collected from all selected vegetation types recovered from all elevation strata. This layout eliminated confounding between vegetation type and elevation.

Four vegetation types were selected for study:

- Barren soil where no vegetation was growing. It was collected from existing barren sites at lowest elevations;
- Fall rye planted in 1999. It was collected from sites where a fall rye monoculture was growing;
- Reed canary grass. It was collected from sites where mixed perennial native grasses were thriving; and
- Lenticulate sedge (*Carex lenticularis*). It was collected from sites where sedge and perennial native grasses were thriving.

Fall rye was selected because of interest in potential benefits it may provide beyond its primary purpose of providing dust control after planting each year. Reed canary grass and lenticulate sedge were selected because they were two of the most abundant and common plant species at mixed vegetation sites. These two species were considered most representative of the mixed plant communities (A. Moody, AIM Consultants. pers. comm.).

Three elevation and vegetation combinations were selected to cover the range throughout the Revelstoke Reach:

- Lowest elevation (430.9 m) characterized by barren sediment or soil, hereafter called the barren site;
- Low elevation where fall rye was planted in 1999 (431.2 m), hereafter called the fall rye site; and
- A high elevation stratum supporting mixed native vegetation (435.6 m), hereafter called the mixed vegetation site.

Actual elevations of these strata were determined in two steps. The strata were first identified from existing air photo coverage reported by Carr et al. (1993). Actual elevations were the water surface elevations of the Arrow Lakes Reservoir at the time the water elevation passed the vegetation zone during reservoir filling in 1999.

Two dates were selected to cover the anticipated period of biofilm accrual and invertebrate colonization on plant material:

- T=1 was within 10 days after inundation to examine the initial community associated with the flooded foliage and root masses; and
- T=2 was approximately 80 days after inundation to examine what was expected to be a fully developed community associated with the flooded foliage and root masses remaining at that time.

Samples were also collected immediately before inundation to capture terrestrial invertebrates on the aboveground foliage and in the belowground root and soil matrix. These samples were not further examined in this project because they were unrelated to processes after flooding.

By random selection of the plants, the experiment contained two factors (vegetation type and elevation) that could be independently analyzed within one or each of the two time blocks. Alternatively, time could be another factor to support a 3-factor design. Each of these layouts was a randomized complete block design that could be analyzed using multi-factor analysis of variance. Three replicates were arbitrarily assigned. Endpoints that could be examined in the analysis were:

- Direct measures or indices of invertebrate abundance, composition and diversity associated with aboveground plant foliage and belowground soils, sediment, and plant roots;
- Invertebrate biomass associated with aboveground plant foliage and belowground soils, sediment, and plant roots;
- Periphyton abundance, composition and diversity on plant leaf matter;
- Plant nutrient content (reported by AIM and Carr 2000); and
- Plant biomass (reported by AIM and Carr 2000).

To determine rates of colonization, one sample of each vegetation type that was outplanted in separate containers was collected weekly for an 8 week period after T=1. The high elevation mixed vegetation site was used for all collections. All endpoints were the same as those measured in the main experiment, including invertebrate abundance, nutrient content of vegetation, etc. The most important data in these measurements was change in biomass of benthic invertebrates.

3.2.2 Fish

Because fish can move around the reach, a separate design was required to examine associations of fish and vegetation type. Examination of fish associated with small outplanted plants was not an option. No quantitative fish survey had been completed in the reach before this project, leaving little evidence of distribution, species composition, and abundance at any location. Because these preliminary data were lacking, a simple design of examining spatial variation in fish endpoints across replicated areas of the reach containing the three vegetation strata was selected (Map 7). The location strata were consistent with those used in the outplanting experiment and they included barren sites, barren areas planted with fall rye in 1999, and areas where native vegetation was present.

Potential confounding of measurements of fish abundance and species composition among location strata was movement of fish between locations. Fish that move in to new shallow habitat with the rising water surface elevations in spring may be there for several reasons. Rainbow trout may move to spawning streams with rising water, which means that their capture may have nothing to do with direct utilization of the newly-flooded habitat. Fish may eat terrestrial insects that are entrained with rising water but then leave for other habitat after that food supply is depleted. Still others may move in to stay in newly-flooded habitat for the duration of the summer growing season using food associated with the plant biofilm and soils.

To minimize risk of confounding, fish sampling occurred in September, which is relatively late in the growing season when fish movement was expected to be less than earlier in the growing season. Fish found at a given location in the late summer were more likely to be directly using the habitat as opposed to simply moving through. For this reason, data collected later in the summer was interpreted with greater confidence than would have been the case with spring data.

3.3 Results

3.3.1 Periphyton

Periphyton on all plants was comprised mainly of diatoms and filamentous green algae. Densities on leaves were <18,000 cells/cm^2 and most were <6000 cells/cm^2. In comparison to other oligotrophic systems, these densities were extremely low. Lab methods used to remove confounding effects of extensive silt and sand in the samples were found to yield underestimates of actual cell densities.

3.3.2 Invertebrates

A total of 66 benthic invertebrate taxa including naidid, enchytrid, and lumbriculid worms, nematodes, ostracods, tubificids, water mites, gastropods, aquatic insects, beetles, terrestrial insects, zooplankton, and freshwater shrimp were found in aboveground and belowground plant samples. Most abundant were the oligochaete worms, nematodes and ostracods. Benthos densities reached 43,727 animals·m^{-2} in aboveground samples and almost 64,000 animals·m^{-2} in belowground samples. These densities were very high compared to those in other oligotrophic systems.

Vegetation establishment increased the areal biomass of benthic invertebrates by two to four times over that found in barren soils. The submersed vegetation greatly increased the areal extent of substrata for colonization by benthos, allowing a diverse and abundant fauna to flourish. While the simple presence of plants increased benthic invertebrate biomass, invertebrates favoured dead and decaying plant matter (fall rye) over submersed living plants (lenticulate sedge and reed canary grass). The plant-benthos link was mediated by the epiphytic biofilm in which benthic diatoms were a major component. Direct feeding on dead and decaying plant matter was a major process contributing to the association between benthos and fall rye.

3.3.3 Fish

It was here that further links to the aquatic ecosystem appeared truncated. Sucker species that are mainly detritivous feeders may have responded to increased benthos in association with dead and decaying fall rye but we could find no link between the plant – benthos association and sport fish that are mainly visual predators. Sportfish (rainbow trout) were eating mainly terrestrial invertebrates that landed on the water surface. There was no evidence of these fish eating taxa found in association with the plant substrata. One reason for this outcome was that benthos were generally not available to visual feeding habits of those species. In this respect, the establishment of vegetation in the drawdown zone of Revelstoke Reach greatly increased the capacity of the reach to host a diverse and abundant benthic community but it did not directly lead to an equal change in abundance of sportfish.

Notwithstanding this finding, a small fishery is now present in the reach where it was not present before vegetation establishment. Cover is available in shallow habitat for fish to use as they mainly feed on surface organisms. An abundance of terrestrial invertebrates may use the vegetation in the spring and become inundated with rising water. These invertebrates may not be directly associated with plant substrata after flooding (and thus not found in our samples) but may provide an abundance of food for sportfish in the water column and on the water surface when the water surface elevation is rising. Detection of this process was not included in our experimental design but may be an important factor explaining the presence of surface-feeding sportfish and the presence of a fishery based mainly on fly gear.

Fish may move in and out of vegetation cover, potentially confounding our ability to distinguish effects of location on fish presence, absence, and abundance. If this project is pursued further, the focus must clearly be placed on improving ways to quantitatively resolve this link between the strong association of benthos and plants with higher trophic levels. Recommended techniques include radio tracking fish and following stable isotopes between trophic levels.

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4.0 Wildlife Studies in the Upper Arrow Reservoir Revegetation Zone

As part of the Upper Arrow Revegetation Ancillary Benefits project, funding was provided to the Friends of Mount Revelstoke and Glacier in Revelstoke to coordinate the wildlife studies component. The wildlife component involved a study to examine the songbird use of the Upper Arrow Reservoir floodplain, operation of annual songbird monitoring station in the Upper Arrow Reservoir and compilation of an Upper Arrow Reservoir waterfowl database. A description of each of these three components follows.

4.1 Songbird Use of Four Floodplain Vegetation Types in the Revelstoke Reach, Upper Arrow Reservoir

John Boulanger, Integrated Ecological Research, John G. Woods, Parks Canada - Mount Revelstoke and Glacier National Parks and Janice Jarvis, Revelstoke

4.1.2 Introduction

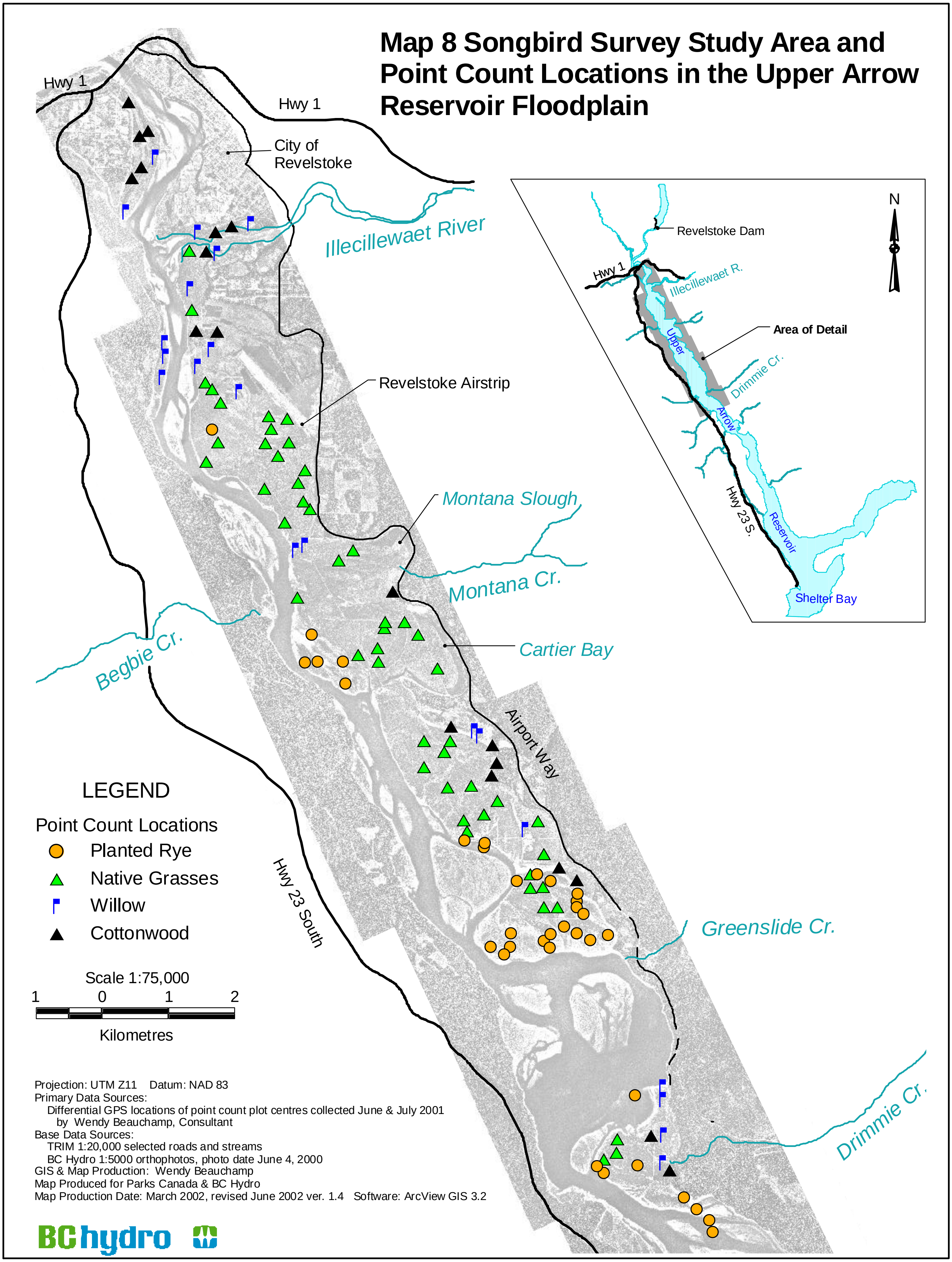
The study involved a survey of bird use of four terrestrial vegetation types within the flooding zone of the Upper Arrow Reservoir during a year of little or no flooding, including cottonwood, willow, native grasses and fall rye (Map 8). The survey examined bird density and the estimated number of species present (species richness) in the four floodplain habitats. In addition, habitats were compared using species diversity indices that consider both the abundance and richness of species to index the relative balance of species in a habitat. Demographic analysis was undertaken to estimate the relative fidelity and rate of additions of species to habitat areas over the course of the survey.

4.1.3 Field methods

Terrestrial vegetation within the flooded zone was stratified into 4 classes: planted Fall Rye, native grasses, willow shrub, and cottonwood (Photos a-e). These four vegetation classes roughly correlated with elevation. Fall Rye was planted annually in the lowest zones (with the most persistent flooding). Native grasses included a complex of grasses, sedges, and horsetails with no shrubs that naturally invaded the floodplain and were typically found between the Fall Rye and the Willow Shrub. The Willow Shrub class had variable shrub density of 1+ stems and typically was located between the Native Grasses class and the Cottonwood class. The Cottonwood class had a variable density of 1+ cottonwood stems and was at the highest elevation below the maximum reservoir elevation.

This study area included that portion of the floodplain on the east side of the reservoir from the Trans-Canada Highway bridge at Revelstoke to Drimmie Creek and the west side of the reservoir from the Trans-Canada Highway bridge to Tonkawatla Creek. Using orthophotographs taken at low water levels, a set of randomly selected survey points was generated for each vegetation class. Although an attempt was made to have equal numbers of survey sites in each vegetation stratum, this was not possible because of unequal availability. One hundred and thirty-two sample sites were identified.

Map 8 Songbird Survey Study Area and Point Count Locations in the Upper Arrow Reservoir Floodplain



Each site was visited at 15-day intervals from May 16 to July 31, 2001 (5 samples per site maximum) within 4 hours after astronomical sunrise. Time of visit was not consistent between samples. During each site visit and observer would conduct a 5 minute point count by actively scanning by sight and sound for any species identifiable from the site. Species were recorded as within or outside of 50 m and notes made on numbers and activity (e.g., flying, singing). In addition, the observer made a sound recording of the entire 5-minute sample using minidisc recorders and an external microphone. These recordings were then reviewed by an independent observer to verify species identity.

During each point count, the observer also noted birds detected outside the 50 m plot, but within the floodplain. Sampling was discontinued during periods of heavy rain or fog.

Field notes were then transcribed into an Access database.


Photo a. Fall rye shortly after planting (April 2001) Photo b. Fall rye in mid-summer (July 2001)
a.) Parks Canada: Michael Morris photograph b) BC Hydro: Janice Jarvis photograph

Photo c. Native grasses vegetation type. Parks Canada: J. Woods photograph.

Figure d. Willow vegetation type. Parks Canada: J. Woods photograph.

Photo e. Cottonwood habitat type. Parks Canada: J. Woods photograph.

4.1.4 Results

Seventy-four species of birds were recorded at <50 m and 12 additional species were seen within the floodplain but not within any 50 m point count. In terms of species richness, species diversity, and bird abundance, cottonwood and willow habitats received more use than planted Fall Rye or native grass habitats.

Cumulative bird lists for each habitat included: 54 species in cottonwood habitat; 47 species in willow habitat; 35 species in native grasses habitat; and, 32 species in planted Fall Rye habitat. Analysis results suggest that cottonwood and willow habitat types had the highest number of species occurring during surveys when compared to native grass and planted rye. In addition, cottonwood and willow habitat types had the highest density of birds, and highest species diversity of habitat types surveyed.

Little is known of the complex interplay between water levels, soil erosion, natural vegetation colonization, and vegetation management in this system. While it is apparent that birds use these vegetation types both during migration and the breeding season, the demographic consequences for any species are unknown. Previous studies have documented use of the area by waterbirds throughout the year (Jarvis and Woods 2002) and by land birds during autumn migration (Anonymous 1998, 1999, Jarvis and Woods 2000, Jarvis 2001). This project was the first major survey of bird use of the draw down zone at Revelstoke during the breeding season. . Several species of rare birds were observed during this study including the first Short-eared Owl breeding evidence at Revelstoke in June and a probable migrant Loggerhead Shrike in May.

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4.2 Upper Arrow Reservoir Songbird Banding Project

Janice Jarvis, Revelstoke, BC

4.2.1 Introduction

The Canadian Wildlife Service (CWS), Parks Canada, and Friends of Mount Revelstoke and Glacier established the Columbia River-Revelstoke Migration Monitoring Station (CRR) in 1998 to track land bird migration activity and provide information on their migration and habitat needs while involving the local community. The CRR station has run since 1998 as a trial project with the goal of setting up a long-term monitoring station that becomes part of the Canadian Migration Monitoring Network (CMMN). The CRR completed the 4th year of operations banding 2198 birds during the 2001 fall migration-banding season and will prepare a submission to the CMMN to review for acceptance to the organization.

CRR is located on the Upper Arrow Reservoir on land owned by the Columbia Shuswap Regional District just north of the runway at the Revelstoke Airport. This area know as the Revelstoke Reach Wetlands is very unusual area within the draw down zone of the Columbia River reservoir system because it contains extensive vegetated areas below the reservoir high water level. This area is typically flooded for only a short a period each year and occasionally is not flooded at all. This flooding regime along with a seeding program by BC Hydro has allowed extensive areas of marsh, riparian, and some upland vegetation to survive. In most areas impound by the Columbia River dams, seasonal flooding kills the majority of vegetation below the high water mark and leaves extensive areas of mud and sand flats which are revealed at low water.

4.2.2 Site & Operation

The site of the operations remained the same as the past 3 years. The station's unique location in a functioning reservoir system causes changes the variation of the quantity and quality of habitat and water from year to year. The actual vegetation structure of habitat (willow/cottonwood complex surround by grasslands) has not changed but due to the station being subjected to flooding as part of regular hydro production on the Columbia River system the amount of water and available habitat changes with water levels in the Arrow Reservoir. The station is not subject to flooding but will still have water surrounding the area when Reservoir levels are 438.5m or less of the 440m that are in the drawdown zone. Above the 438.5m level the station becomes flooded with various net lanes be unable to be used as was the case in the beginning of 1999 and 2000 season.

The winter of 2000/2001 was a below average snow pact in the Columbia Basin leaving the station with no flooding problems and leaving the Columbia River with low water, which meant the station was not surrounded or inundated by water for the any of the season. This was similar to the 1998-banding season, which had a high Reservoir level of 438.5m except that 2001 high was 434m, which is considerable less than full pool for the Reservoir and create much more open grassland complex over the entire Revelstoke Reach area with less water available.

The general operations of the site remained fairly consisted with past years. CRR is operated using a system know as 'Standard effort method', a system that uses the same net lanes and protocols (methods) year after year. This method allows data to be compared from year to year and with other stations throughout North America. 'Net hours', the number of nets times the number of hours they are open is used to standardize effort as birds captured per net hour. There are many factors that reduce the potential maximum number of net hours (e.g., 6 hours per day for the whole period of banding times the number of operational nets) including wind, rain, and lack of trained personnel to handle birds. A normal day of operation began 30 minutes before sunrise for a standard 6-hour period with 10-12 nets open

This year the banding operations began on August 1 and ran until September 30 for 56 days of banding (50 full days and 6 partial days). A total of 2198 birds were capture in the 3468.6 net hours for an average of 0.63 birds per bird. (Table 1) The only change that occurred this year that would affect data collection was the start of a daily census and general observations nearly every day for the month of August. A daily census is a fixed route followed by an observer at a set time that records all birds seen and/or heard. The census along with general observations and daily banding totals allows a calculation of 'estimated totals' (ET), which incorporates species not caught to be recorded, (see Appendix 5 for species list) and is currently being used in many migration monitoring stations through out North America. The data from the census will not be used for this year, as there was not consist coverage and the protocol for tabulating the totals needs to be reviewed and adapted to the station. The hiring of an assistant for the month of August who had the necessary skills to do this allowed for this to happen for the first time in the 4 years and will be a goal for future years.

Table 1: Columbia River - Revelstoke
Bird Monitoring Station Summary Statistics 1998-2000

Year	Birds Handled	Banding Days	Net Hours	Birds per Net Hour
1998	2748	42	2247	1.22
1999	1139	45	1687	0.68
2000	1563	47	2331	0.67
2001	2198	56	3468.6	0.63
Total	7648	190	9723.6	0.79

4.2.3 Banded Birds

There was a total 1389 individual new birds banded, 752 recaptures, and 57 unbanded birds for a total of 2198. A total of 54 species were captured in the mist nets with 53 being banded and/or processed, while 1 species (Rufous Hummingbird) was released unbanded at the nets whenever encountered. There was the capture of 3 species which are considered rare for this area: 1 'after hatch year' Cassin's Vireo on September 8; 1 'hatch year' female Connecticut Warbler on

September 12(never recorded before in this area); 1 'hatch year' male Chestnut-side Warbler on September 30. Birds that are banded are expect to be aged using methods recognized by the Banding Office to 'After-Hatch Year' (a bird born in a previous year) or 'Hatch Year' (a bird that was born that year), and for some species 'Second Year', 'After Second Year' and 'After Third Year'. During the fall migration season it usually only possible to distinguish between an 'After Hatch Year' or 'Hatch Year' do to the loss of feathers or other characteristics that make it possible to tell a 'Second Year' bird from other 'After Hatch Year' birds.

Of the 2,141 birds that were processed in the 2001 season a total of 1,817 were birds that were aged as 'hatch year' and 324 were aged as 'After hatch Year', 'After Second Year', or 'Second Year'. If one looks at the individuals and their age ratios, we discover a 5.6:1 ratio of 'Hatch year' to 'After Hatch Year'. This is common and expected after a successful breeding season, as the breeding birds should be able to fledge a good number of 'hatch year' birds to maintain populations as the survival rate of 'hatch year' birds are low. This ratio is a higher ratio than the Vaseux Lake Bird Observatory (Hunter 2001) for the 2001(2:1) season but will need to have further years of study to be able to determine a ratio for this area.

If isolated and analyzed the five most common species Common Yellowthroats, Yellow-rumped Warblers, Traill's Flycatcher, Orange-crowned Warbler and Yellow Warbler we discover a large variance in the ratios (Table 2). The variance between species may be a factor of a number of items including but not limited to: 'After Hatch Year' birds migrate earlier, may not use the same stop-over or resting place that 'hatch year' birds do; 'After Hatch Year' birds are more careful than 'hatch year' birds, therefore not as likely to end up in nets; there are more 'hatch year' birds to be caught in the fall due to the survival rates.

Figure 2: Ratio of 'Hatch Year' Birds to 'After Hatch Year' Of the 5 Top Species

Species	Total number birds handled	Ratio
Common Yellowthroat	565	5.6:1
Yellow-rumped Warblers	239	7.5: 1
Traill's Flycatcher	194	4:1
Orange-crowned Warbler	185	45:1
Yellow Warbler	148	3:1

4.2.4 Sexing

The 2001 banding season saw 923 of the 2,141 birds banded (43%) could not be sexed and left in the 'Unknown Sex' category. There were 817 birds (38%) identified as males and 403 birds (18%) identified as females. The banding season falls outside of the breeding season for most of the species caught at the CRR Station. This makes sexing of individuals hard for species that have the same plumage for male and females or may not be able to be sexed unless certain characteristics appear leaving a large number of birds in the 'unknown' category of sex.

One reason that more birds were identified as male than females may be due to the fact that many of the top species at the CRR station can be 'hatch year males' if they show certain characteristics, but if they don't show those characteristics they need to be classed as 'unknown', *e.g. A 'hatch year' common yellowthroat if it shows some of a black mask it can be classed as male but if they don't it needs to be identified as 'unknown' as it may develop the black mask through the next number of months or might be a female.*

4.2.5 Recaptures

There were a total of 752 records of recaptured birds for the 2001 season. A 'Recaptured bird' is any bird that has band on it when taken from the net regardless of when it was banded. This number may be missing leading as many of the recaptures are birds that were newly banded this year. The vast majority of these birds are using the place for stop over foraging habitat for few days or birds that are locally breeding birds. By tracking the recaptures we are able to track some birds length of stopover, molting patterns and sequence, and weight gain or loss. This information will enable a better status of certain species to be obtained over the long-term.

Not all of this years 'recaptures' are birds that were banded in the 2001 season at the CRR. There were 45 of birds that were either banded in other years at CRR or other banding locations in the area.

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4.3 Waterbirds of the Revelstoke Reach Wetlands, Upper Arrow Reservoir, Revelstoke, British Columbia, Canada

Janice Jarvis, Revelstoke
John G. Woods, Parks Canada - Mount Revelstoke and Glacier National Parks

From January 1991 to March 2001 waterbirds were surveyed from fixed points along 12 kilometers of the eastern shoreline of the northern portion of Upper Arrow Reservoir, known as the Revelstoke Reach wetlands. These surveys documented 65 species of waterbirds using the Reach with large variations in species richness and abundance by month and zone. The area with the greatest species richness and individual abundance had the most stable water regime. The greatest species diversity and individual abundance occurred during the spring and the least during the winter and summer. Several species appeared to be regular breeders but summer flooding may limit reproduction opportunities. There were large month-to-month variations in water levels on the Reach and flooding patterns and timing varied from year-to-year. Within the Columbia River hydroelectric reservoir system, the Revelstoke Reach wetlands appear to be unique in terms of amount of persistent vegetation below the maximum reservoir level. An ACCESS database has been prepared to facilitate further analysis.

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5.0 Simulating the Response of Aquatic and Riparian Productivity to Reservoir Operations: Description of the Vegetation and Littoral Components of BC Hydro's Integrated Response Model (IRM)

Josh Korman
Ecometric Research Inc.

5.1 Background

A simulation model, predicting the response of riparian vegetation and benthos produced in the littoral zone to water surface elevation schedules and fall rye planting in storage reservoirs was developed. The intent of the modeling effort was to provide a predictive tool for water management, but more importantly, to highlight key gaps in data and understanding to strengthen future monitoring and research efforts. Model development was a collaborative effort that integrated data and hypotheses from vegetation ecologists and limnologists who were actively working in the Revelstoke Reach of the Arrow Reservoir, British Columbia.

5.2 Model Parameters

The vegetation component of the simulation model makes predictions about changes in biomass of various plant groups on a weekly timestep over the growing season. A multi-year sequence of average weekly reservoir water surface elevations is provided as input to the model. In conjunction with a digital elevation model, this time series is used to compute statistics on wet and dry stresses that are accumulated at each 1-meter elevation band in the reservoir. These stress statistics in turn are used to determine seedling establishment rates, and the survival and growth rates of mature plants. The groups of plants that are simulated are: fall rye, horsetail, reed canary grass, sedge, willow, and cottonwood. These plant groups were defined based on differences in growth rates, their responses to wet and dry stress, and their importance to wildlife habitat. A summary of the data used to parameterize the model and model dynamics is provided.

Two major weaknesses in our understanding of the response of vegetation to reservoir operations and fall rye planting were identified in the modeling process. There is almost a complete absence of multi-year data collected in a consistent manner from an informative monitoring design. The lack of this type of information makes it difficult to separate the effects of wet and dry stress on growth, survival, and seedling establishment. The other major uncertainty identified in the model development process was the lack of quantitative understanding of the effects of fall rye planting on native vegetation establishment.

The littoral-benthic component of the simulation model predicts the production of benthos on an annual timestep for 1-meter elevation bands in the reservoir. The two key processes that are simulated are the effects of inundation and flooding of vegetation. The contribution of fall rye, and to a lesser extent reed canary grass and sedge, to the total littoral biomass in the Revelstoke Reach of Arrow Reservoir is potentially very large. Fall rye generates about 12 mg dry wt/g plant after 10 wks of inundation, a value that is almost an order of magnitude higher than the estimates for sedge and reed canary grass). Fall rye is 5-fold more productive that native vegetation. Taken together, these data imply that flooded fall rye generates about 50 times more benthic invertebrates per m^2 relative to that from sedge or reed canary grass in situations when these vegetation groups are at maximum biomass levels. There is large uncertainty about whether this contribution to benthic production is translated into any benefits for fish populations.

Recommendations for the design of future monitoring programs and model improvements are provided along with a user's guide describing the installation and operating procedures for the simulation model.

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6.0 Aesthetic and Recreational Benefits

Michael McPhee, Quadra Planning Consultants Ltd.
Marc Pedersen, BC Hydro Research Services

While most of the focus of the SEIP in the Upper Arrow Reservoir was on determining ecological impacts of the revegetation growth, the project was also concerned with how people living in and around Revelstoke perceived the revegetation growth in terms of aesthetics and recreational use. Two studies were carried out to address the aesthetic and recreation benefits.

The first study involved a comprehensive telephone survey of approximately 400 Revelstoke residents (BC Hydro Research Services, 2001). This study examined the awareness of the reseeding program by residents and their attitudes towards the aesthetics of the revegetation growth, their recreation use of the drawdown zone and whether or not the revegetation had resulted in an increase or decrease in recreational use.

The second study reviewed the recreational activities of organized recreation clubs within the Upper Arrow Reservoir drawdown zone (McPhee, 2002). This involved interviews with representatives of clubs to determine outdoor recreational activity use patterns.

6.1 Aesthetic and Other Social Benefits of Revegetation (BCH 2001)

Arrow Lake Reservoir was created in the 1960s and 1970s as a result of the construction of the Hugh Keenleyside Dam near Castlegar. While the reservoir plays a prominent role as one of three flood control and energy storage facilities built under the Columbia River Treaty, it also serves the communities around it by way of the many different outdoor recreational activities it affords. With the Upper Arrow Reservoir's adjacency to Revelstoke, it has provided that city's residents a natural outdoor playground for a host of different pursuits such as fishing, boating, swimming, hiking, cycling, and wildlife viewing – just to name a few.

The Upper Arrow Reservoir's proximity to Revelstoke presented a unique problem in the past to the region and its residents – namely, dust storms. To facilitate flood control and power generation under the terms of the Columbia River Treaty, the reservoir is drawn down annually from about November to June, with water levels at their lowest in the spring before snowmelt and runoff. During these times, exposed shorelines that do not support natural vegetation have been subject to severe dust storms when windy conditions have arisen.

Having observed this dust storm phenomena from its onset in the 1970s, BC Hydro took steps to mitigate them by seeding the exposed reservoir areas with fall rye. By doing so, plant vegetation grows in the areas where at one time was only dirt, helping to prevent dust and dirt becoming airborne when the reservoir water level is low. A more formal dust control program was implemented in 1986 which sees the annual seeding of the most vulnerable shoreline areas of the reservoir system – particularly those between Revelstoke and Shelter Bay. The vegetation growth in the Upper Arrow Reservoir has resulted in a visible "greening up" of the area.

To determine how residents perceive this "greening up" of the drawdown zone and the impact it is having on recreational use of the area, the SEIP project with assistance from BC Hydro's Research Services, undertook a telephone survey of Revelstoke residents. The study had the following objectives:

- Gain an insight into residents' perceptions of the reservoir system – both as it is now and how it may have changed over the past five to ten years
- Measure awareness of the seeding program, understanding of its purpose, and its sponsor
- Measure the perceived impact of the seeding program on the areas in and around the reservoir
- Measure recreation use of the area, participation rates in the different outdoor activities, and what specific areas are most commonly visited

The study also examined what environmental issues were of most importance to the residents of the area. These are not addressed here, but are available in the full report (BC Hydro Research Services, 2001).

A total of 400 telephone interviews were conducted with a random sample of adult residents of Revelstoke. MarkTrend Research in Vancouver conducted interviewing during the afternoons and evenings between July 12th and July 24th, 2001,. Quotas were applied by gender and age in an effort to ensure the sample was representative of Revelstoke based on current Statistics Canada data. However, to correct for an under-representation of 18 to 35 year olds, the data was weighted at the tabulation stage such that the sample did truly reflect the area's age composition.

At the 95 percent level of confidence, the maximum margin of error for the total sample size of 400 is +/- 4.9 percent. This is based on a 50/50 split in consensus to any given question. As the level of consensus on a question increases, the margin of error decreases. For example, for the total sample size of 400, if 90 percent of residents respond a particular way to a question, then the margin of error at the 95 percent level of confidence decreases to +/- 2.9 percent.

6.1.1 Survey Results

Before engaging survey respondents in a dialogue about the Upper Arrow seeding program, they were first asked to think about the current reservoir system and its surroundings between Revelstoke and Shelter Bay on a number of different dimensions, and to what extent those dimensions may have changed over the past five to ten years. Without prompting, it was the respondents themselves who brought the seeding program into the discussion.

The majority of residents rate the shoreline areas around the Upper Arrow Reservoir between Revelstoke and Shelter Bay as either "excellent" or "good" (75%) rather than "fair", "poor" or "very poor" in terms of the *amount of its green plant vegetation*. This positive sentiment is further complemented by the finding that the largest segment of individuals – 46 percent –

believe that the amount of green plant vegetation has "improved" over the past five to ten years rather than "stayed the same" (37%) or "deteriorated" (9%). Among residents who believe there has been a significant improvement in this regard, about nine in ten of them name the seeding program and re-growth – on an unaided basis – as being the primary reason for what they perceive to be a positive change.

Seven in ten residents rate the areas in and around the Upper Arrow Reservoir between Revelstoke and Shelter Bay as either "excellent" or "good" in terms of their *looks being pleasing to the eye* (70%). While the largest proportion of residents believe that the aesthetics of the area have stayed much the same (42%) over the past five to ten years, the balance of individuals are significantly more likely to feel that they have improved (34%) rather than worsened (16%). Among individuals feeling that the look of the areas are much better than they once were, close to eight in ten of them point to the seeding program as the impetus behind the change.

Nearly two in three residents assess the *air quality* in the Revelstoke area as either "excellent" or "good" in terms of *being free of pollution and dust* (64%). While 54 percent of them feel current air conditions are much the same as they were five to ten years ago, almost three times as many believe they have "improved" rather than "deteriorated" (31% versus 12%). Once again, among those who feel the air quality in the Revelstoke region has improved a great deal during this time, about eight in ten of them point to the seeding program and re-growth as being the main reason for the turnaround.

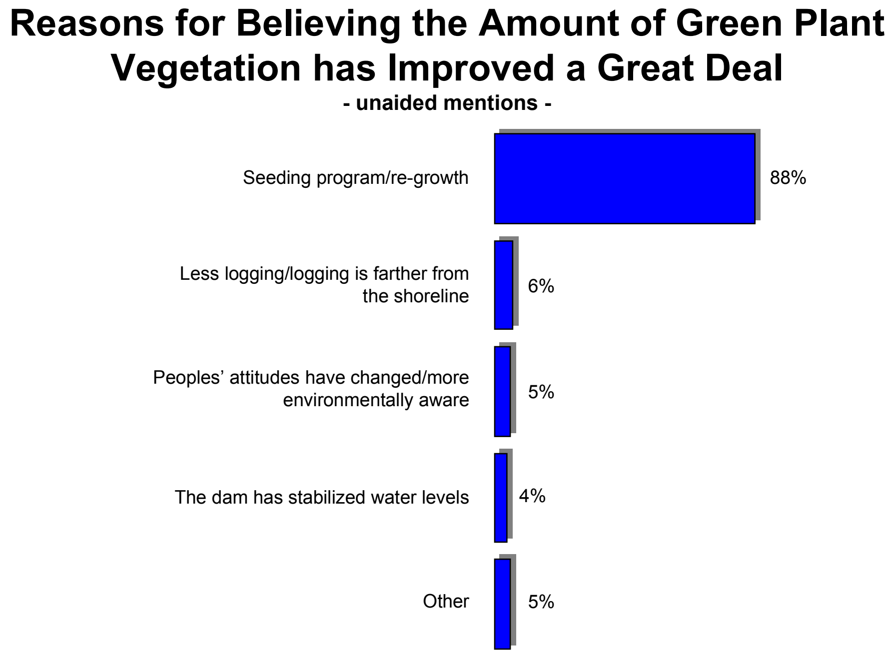
About six in ten residents rate the areas in or around the edges of the Upper Arrow Reservoir between Revelstoke and Shelter Bay favourably in terms of the *ability to participate in outdoor recreational activities* (59%). While 61 percent of individuals believe there has been no change over the past decade in the recreational opportunities the areas afford, twice as many feel there has been an improvement in this regard rather than a deterioration (24% versus 12%). Unlike the previous three dimensions investigated, no one reason stands out by itself as to why some residents feel the ability to participate in recreational activities in these areas has improved a great deal. Instead, these individuals point to a number of different reasons or even outcomes – easier access to the reservoir, more boat launches, the seeding program, a cleaner lake, and more recreational users.

Forty seven percent of respondents rated *the quality of fish & wildlife habitat* in and around the Upper Arrow Reservoir as either "excellent" or "good". Thirty nine percent of respondents believe that the quality of fish & wildlife habitat has "stayed the same" over the past five to ten years, 33% believe it has "deteriorated" and 17% believe it has "improved".

Though not referenced with the same overwhelming frequency as on some of the other dimensions, the seeding program and re-growth emerges once again at the top of the list of reasons why a few individuals believe the fish & wildlife habitat has improved.

Awareness of the Upper Arrow Seeding Program

While only about one in ten residents are able to name the shoreline seeding program as an environmental initiative currently underway in their region that relates to the Upper Arrow Reservoir between Revelstoke and Shelter Bay, awareness does shoot to eight in ten on an aided



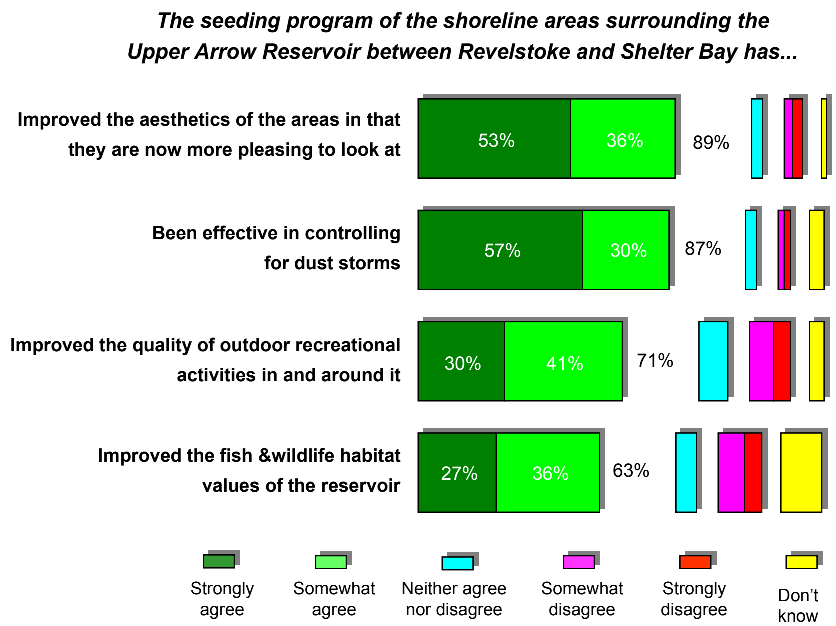
basis. These residents do not need to be reminded, however, of the program's primary purpose – eight in ten of them knowing that it is to help mitigate dust storms that can occur when the reservoir's water level is low. Further to this, it is pleasing to note that nearly two in three of those aware of the seeding program name BC Hydro, unaided once again, as its main sponsor.

Perceived Benefits of the Upper Arrow Seeding Program

When asked to think about the impact of the seeding program on the Upper Arrow Reservoir between Revelstoke and Shelter Bay, an overwhelming majority of residents are in agreement that it has *improved the aesthetics of the areas in that they are now more pleasing to look at* (89%), and that it has been *effective in controlling for dust storms* (87%). Many respondents are also in agreement that the seeding program has *improved the quality of outdoor recreational activities* in and around the reservoir system (71%), and that it has *improved the fish & wildlife habitat values* in and around it (63%). The specific level of agreement on these last two dimensions does vary from person to person, depending on which types of outdoor recreational activities they use the area for.

For each of the four dimensions, individuals not in agreement are significantly more likely to be neutral in their opinion rather than critical or contentious of the program's success.

Attitudes towards the Upper Arrow Seeding Program



6.2 Recreational Use of the Upper Arrow Reservoir

Recreational use of the Upper Arrow Reservoir was determined through two methodologies. The telephone survey was able to examine comprehensively the recreational activities of individuals using the Upper Arrow Reservoir. This was a broad survey which focused primarily on unorganized recreational use by residents in Revelstoke. Face-to face interviews were also conducted with executive members of various organized recreation clubs within Revelstoke to determine the recreation activities and recreation locations of club members within the Upper Arrow Reservoir. The results of each survey are discussed below.

6.2.1 Telephone Survey Results

Public opinion is somewhat mixed in regards to the *water level on the Upper Arrow Reservoir being suitable for recreational activities*. While the largest group of residents do rate the water level as either “excellent” or “good” (38%), the total proportion rating it as “poor” or “very poor” (30%) is not too far behind and, in fact, is larger than the proportion rating it as “fair” (24%). In comparing the suitability of the water level to what it was about a decade ago, just over one-half of residents believe it has stayed the same (53%). Others, however, are twice as likely to say that it has worsened rather than improved (28% versus 13%). Among the very few individuals who believe that the water level has become more conducive to recreational activities, about one-half attribute it to the dam’s operations and efforts to better stabilize the reservoir’s water level.

About three in four Revelstoke residents make use of the areas in and around the Upper Arrow Reservoir between Revelstoke and Shelter Bay to participate in outdoor recreational activities – most doing so with other family members or friends. While they enjoy many different outdoor pursuits in and around the system, troll fishing, hiking/walking, shoreline fishing, camping, cycling, fly-fishing and canoeing/kayaking are among the most popular.

Other major activities include:

Wildlife viewing (not bird) (4%)	ATV (all terrain vehicles) (3%)	Softball/baseball (1%)
Bird watching (4%)	Snowmobiling (3%)	Snowshoeing (1%)
4x4'ing (4%)	Picnicking (3%)	Sailing (1%)
Boating (various/general) (4%)	Dog walking (2%)	Jogging/running (1%)
Dirt biking/motorcycling (3%)	Horseback riding (2%)	Sunbathing (1%)
Mountain biking (3%)	Water skiing (1%)	

While those who participate in outdoor recreational activities in or around the Upper Arrow Reservoir between Revelstoke and Shelter Bay make use of many of its different areas, three emerge as being most widely popular. Indeed, approximately seven in ten of these individuals each report that they typically go to 12 Mile, 6 Mile or Blanket Creek to participate in their recreational activities of choice. Nearly two in three individuals who make use of the Upper Arrow system often visit the area around the airport, while fewer visit Cartier Bay, Montana Slough, Machete Island or Shelter Bay. Rounding out the top ten list of favourite recreational sites are Begbie Falls and Akolkolex. Some outdoor pursuits are more popular at certain sites.

It appears as though the Upper Arrow Reservoir between Revelstoke and Shelter Bay has become more popular and heavily used among area residents over the past five to ten years. Although just under one-half of current users say their recreational usage of the area has stayed the same during this time, many more say they are visiting the areas more often (33%) rather than less often (18%).

Individuals using the areas more often than they have in the past frequently reason that they have had a lifestyle change and are now more interested in such activities, that they now have more free time to participate in such activities, and that there is now easier access to the areas – some having moved closer to them. Those using the areas less often than they did five to ten years ago comment that they have had less time to do so, or that they are less interested, believe that they are getting too old, or feel that the water level of the reservoir has been less than optimal for their specific activities of interest.

As one may have expected, the majority of outdoor recreational enthusiasts who make use of the areas in and around the Upper Arrow Reservoir between Revelstoke and Shelter Bay indicate that they participate either “mostly with other family members” (49%) or “mostly with friends” (31%). The balance of individuals is more likely to make use of the recreational areas “mostly alone” (13%) rather than “mostly with a club or organization” (2%).

Looking deeper into the group compositions, women and those in the middle age bracket are significantly more likely than others to make use of the areas of interest mostly with other family members. With reference to specific recreational activities, those who enjoy boating (general) (70%), power boating (60%), cross country skiing (68%), or swimming (58%) are more likely than others to engage in them with family. Please see the table on the following page for the complete findings.

Men and especially those less than 35 years old are significantly more likely than others to use the recreational areas mostly with friends. Participating with friends is a more common occurrence among those who enjoy dirt biking (66%), 4x4’ing (64%), shoreline fishing (42%), and camping (39%).

Individual use of the reservoir areas for recreational purposes measures fairly evenly among the gender and age sub-groups. By activity, mountain biking (35%), cycling (27%), bird watching (30%), and wildlife viewing (28%) are the activities that are more likely to be enjoyed on an individual basis.

6.2.2 Recreational Club Interviews (McPhee 2002)

Revelstoke has a variety of organizations that utilize the Upper Arrow Reservoir drawdown zone for recreational activities. To determine the extent (both temporal and spatial) of organized recreational activities, personal and telephone interviews were conducted in June 2001 with representatives of 12 recreation clubs in Revelstoke. Clubs were identified through a published list of Recreation Clubs by the City of Revelstoke and by several knowledgeable local residents.

The majority of interviews were conducted in person while several were done via telephone. Where appropriate, interviewees were also asked to map areas of the Upper Arrow Reservoir that they used for their particular recreation activities. If a particular group did not have organized recreation activities the interview guide was not used and a more informal discussion usually followed. Representatives of a few groups did not return phone calls and therefore were not interviewed.

Organized recreation activities in the Upper Arrow Reservoir include jogging, bird watching, all terrain vehicles riding (ATV), canoeing, kayaking, camping, fishing, hunting, horseback riding and model airplane flying. The majority of organized recreation use in the Upper Arrow Reservoir is not directly related to revegetation efforts. However, most interviewees stated that the revegetation had resulted in less dust and the area was more pleasant to use as a result of the vegetation growth. For some recreation activities (i.e., bird watching, jogging and waterfowl hunting), those interviewed felt that revegetation had improved these recreation opportunities. Recreation activities are also seasonal and influenced by water levels in the reservoir. As water levels rise, many areas do not become accessible. For some activities, such as paddling and fishing, the rate of participation tends to increase as the water level rises. Key organized activities are discussed below. Maps 9 and 10 show the generalized locations of some of these activities in the drawdown zone of the Upper Arrow Reservoir.

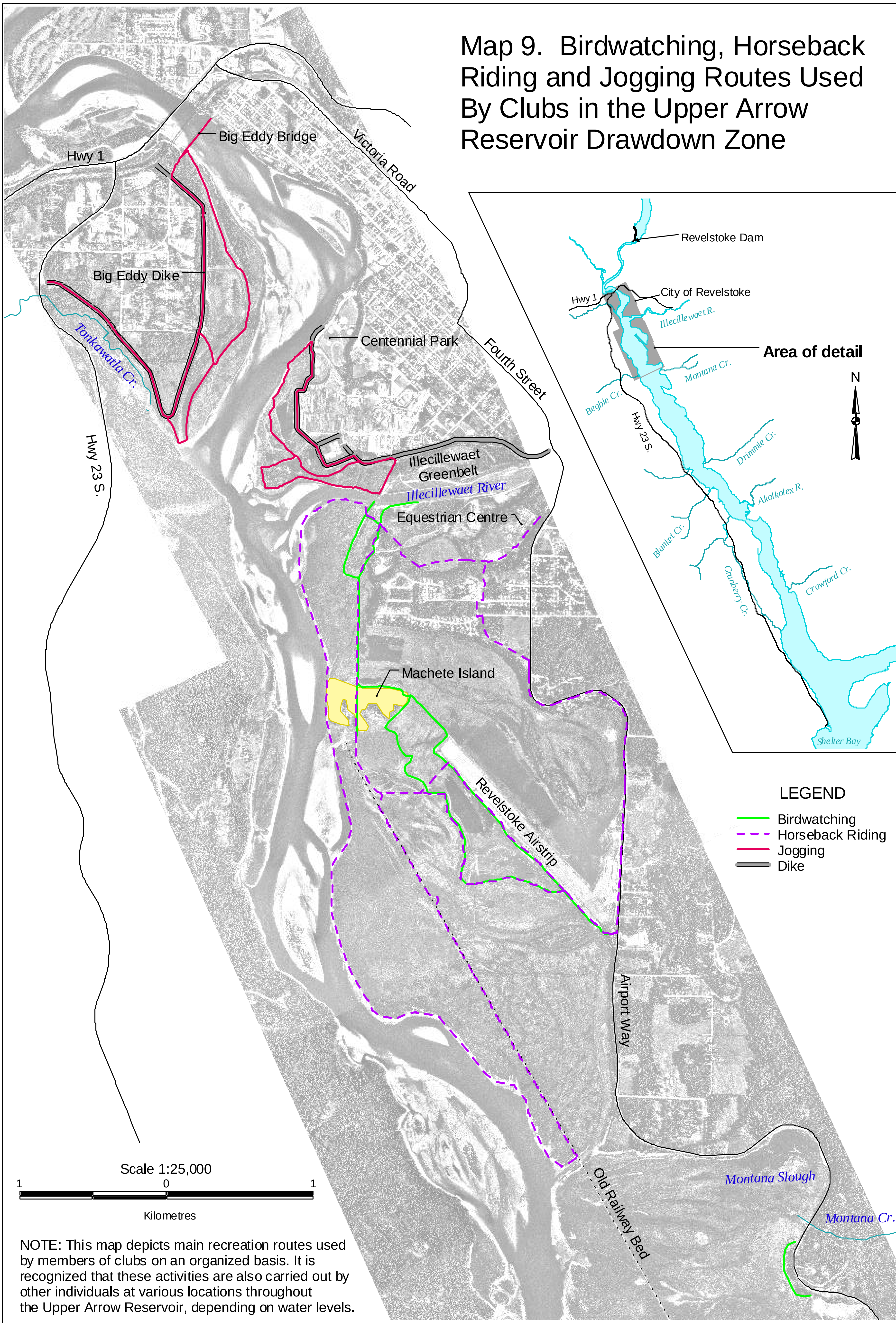
Jogging

Members of the Revelstoke Alpine Runners Society use the reservoir on a regular basis (at low water levels) for jogging. There are approximately 26 members in the society and active members run five times a week between April and November. There is often a slush run in December. The areas most often used include the Big Eddy, the area below the ball diamonds and recreation centre, hooking up with the Greenbelt trail system along the Illecillewaet River (Map 9). According to the President of the club, jogging use of the reservoir area has increased because of the revegetation, mainly due to the general pleasantness of the area and the reduced dust levels.

Bird Watching

The Friends of Mt. Revelstoke and Glacier organize bird watching events in the Upper Arrow Reservoir. The group organizes about two or three bird watching trips per year for its members and the general public (Spring, Summer and Fall). They also run two open houses per year to demonstrate bird banding. The main areas for bird watching are south of the Illecillewaet River to the airport, with Machete Island (north of the airport) being a key area. The Montana Creek area south of the airport is another popular area for bird watching (Map 9). Those interviewed believe that revegetation has led, in general, to more bird use of the area, which in turn has led to more bird watching overall. Of the 225 members of the Friends of Mt. Revelstoke and Glacier, approximately 20 are serious birders. Those interviewed also commented on the fact there is less dust and a more pleasant environment for viewing birds. .

Map 9. Birdwatching, Horseback Riding and Jogging Routes Used By Clubs in the Upper Arrow Reservoir Drawdown Zone



NOTE: This map depicts main recreation routes used by members of clubs on an organized basis. It is recognized that these activities are also carried out by other individuals at various locations throughout the Upper Arrow Reservoir, depending on water levels.

Projection: UTM Z11 Datum: NAD 83
Primary Data Sources: Recreation routes are generalized for map display. Digitized based on interviews with local residents, conducted by Quadra Planning Consultants Ltd., summer 2001. Not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000, selected roads and streams from sheets 82L.099&100
BC Hydro 1:5000 orthophotos, photo date June 4, 2000
GIS & Map Production: Wendy Beauchamp, Consultant. Map produced for Quadra Planning & BC Hydro
Map Production Date: March 2002, revised May 2002 v1.6 Software: ArcView GIS 3.2

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Opportunities for bird watching are lessened as the reservoir water level rises, as there are fewer habitats available to birds and access to the popular birding areas is limited.

Horseback Riding

Horseback riding in the reservoir occurs by members of the Selkirk Saddle Club. From the Club's stables on the south shore of the Illecillewaet River members ride in groups of three or four following road and rail beds south to Montana Slough (Map 9). They ride three or four times a week in spring, summer and fall and in some winters. As reservoir levels rise, they alter their ride routes. Those interviewed stated that their use of the reservoir has gone up since the revegetation program started, mainly because of reduced dust levels. They often observe wildlife in the reservoir on their rides (birds and deer)

Fishing

Members of the Revelstoke Fly Fishers and the Revelstoke Rod and Gun Club organize fishing trips in the Upper Arrow Reservoir. Flyfishing is generally done from boat, drifting with the current. Flyfishers prefer full pool, typically from the end of June to late September and the 12 very active members fish an average of two or three times per week, depending upon wind conditions. Popular boat launching sites include "6 mile", "9 mile" and "12 mile" south of the airport and the reservoir from Montana Slough south to Tank Creek is the primary flyfishing area (Map 10). Shore fishing occurs at a variety of sites along the reservoir, many of which have been targeted for seeding with fall rye by BC Hydro. Shore fishing tends to occur at lower water levels. Those interviewed believe there are more fish available, however, they are uncertain as to whether this is due to revegetation efforts or fertilization of the reservoir.

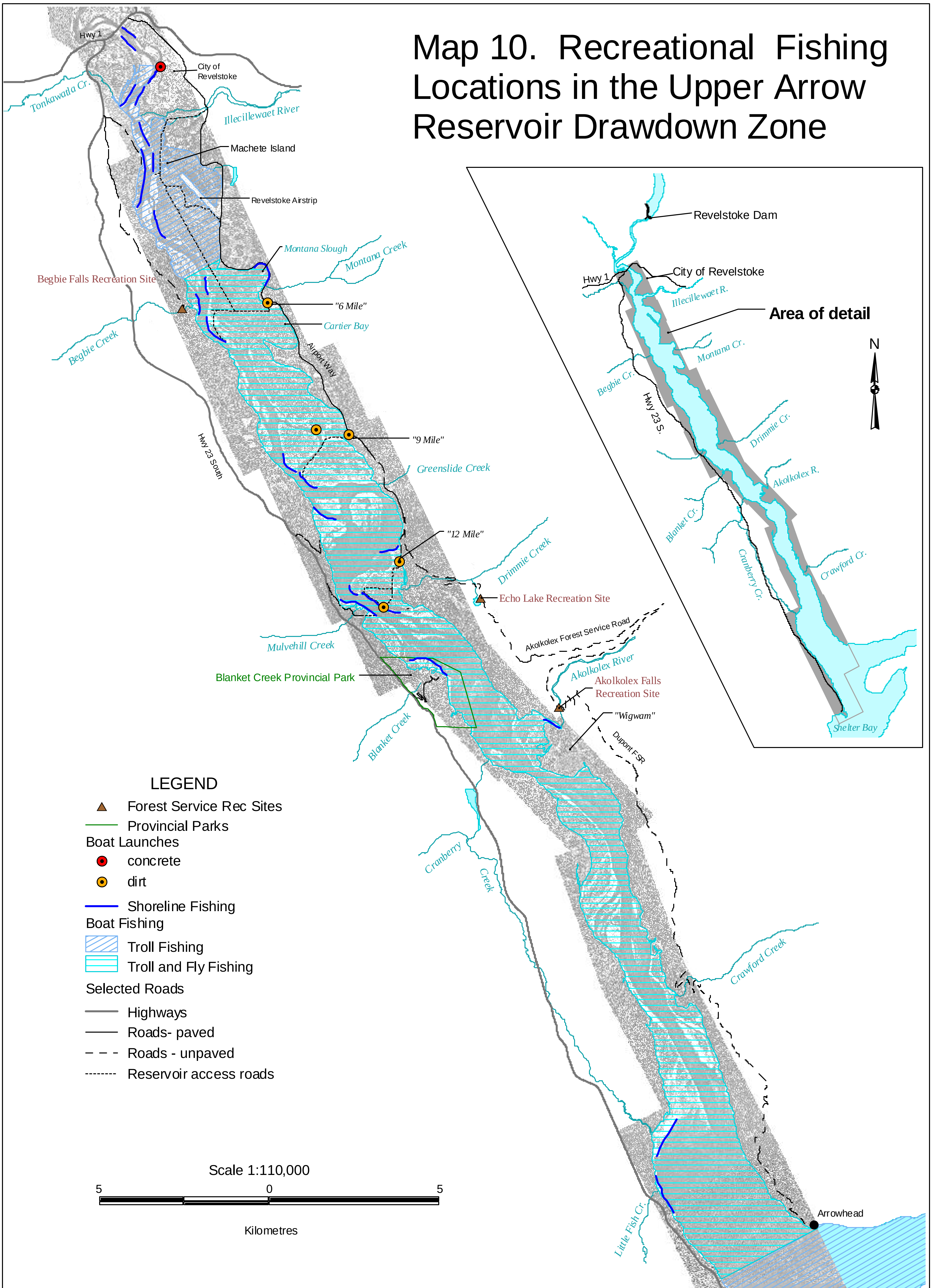
All Terrain Vehicles

Members of the Revelstoke ATV Club use the Upper Arrow Reservoir when water levels are low. Approximately 6-8 of their 45 members rides on a regular basis (two times per month) during low water levels. The riders follow old road and rail beds in the reservoir and logging roads outside the reservoir between Revelstoke and Arrowhead to the south. According to a member of the local club, ATV use has not increased because of the revegetation program in the reservoir. This is due to the fact that ATV users tend to ride along established roads and trails in the reservoir and not the revegetated areas. Those interviewed stated that they tend to avoid greened up areas and said that riding is much more pleasant because of the revegetation. They said that there is more wildlife throughout the area and less dust. ATV use is increasing province-wide. Many ATV users ride snowmobiles in the winter, but not too often in the reservoir.

Canoeing and Kayaking

Canoeing and kayaking trips in the Upper Arrow Reservoir are carried out regularly by several groups including Friends of Mt. Revelstoke and Glacier and the Beavers, Cubs and Scouts. The Friends organize an annual canoe/kayak trip down the reservoir on the Victoria Day long weekend. The Beavers, Cubs and Scouts organize a paddle to Blanket Creek Provincial Park

Map 10. Recreational Fishing Locations in the Upper Arrow Reservoir Drawdown Zone



Projection: UTM Z11 Datum: NAD 83
Primary Data Sources: Recreational fishing areas are generalized for map display. Digitized based on interviews with local residents, conducted by Quadra Planning Consultants Ltd., summer 2001. Not suitable for analysis or legal descriptions.
Base Data Sources:
TRIM 1:20,000 selected roads and streams from sheets 82L.080, .090, .099,.100, 82K.071
BC Hydro 1:5000 orthophotos, photo date June 4, 2000
GIS & Map Production: Wendy Beauchamp, Consultant Map Produced for Quadra Planning & BC Hydro
Map Production Date: March 2002, revised May 2002 v1.7 Software: ArcView GIS 3.2

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each year as well. While the revegetation program has not led to an increase in this activity, it was noted by those interviewed that the vegetation growth has added to the aesthetic enjoyment of using the reservoir.

Hunting

Hunting for waterfowl and larger game (deer, elk, moose and bear) is carried out by members of the Revelstoke Rod and Gun Club. During the fall, hunters hunt two to three times per week. As the reservoir fills, there are fewer opportunities to access popular hunting areas. Montana Slough and Cartier Bay are popular areas for hunting waterfowl while larger game hunting occurs further south in the upper reservoir. Those interviewed believe that the revegetation program has resulted in more game being available and more hunting opportunities. They also stated that there is less dust and a more pleasant environment.

Model Airplane Flying

The Aero Modellers use a field south of the Airport for flying model airplanes. There are about four or five active members. The members meet on Sundays. The field must be mowed and when the reservoir is at full pool, the field is unavailable for use. Another site outside of the reservoir is being considered for this activity. This activity is not really dependent upon the revegetation in the reservoir except that there is less dust as a result of the seeding program.

Other Recreation Activities

There are many other recreation activities carried out in the Upper Arrow Reservoir. However, these activities are carried out mainly by individuals on a casual basis as opposed to organized events. Several other recreation organizations were contacted during this study to determine to what extent, if any, there were organized activities in the Upper Arrow reservoir. These included the Revelstoke Cycling Association and the Nordic Ski Club. The Revelstoke Cycling Association is primarily a mountain biking club and while individual members do ride in the reservoir, there are no organized events. The same is true of the Nordic Ski Club, a cross-country skiing group in Revelstoke. People do cross country ski, but according to representatives of the Nordic Ski Club there is no effort to maintain ski trails in the reservoir. Representatives of the Motocross Club (dirt bikers) and Snowmobile Club were not available for an interview.

A study for the Illecillewaet Greenbelt Society (Waters, 2000) also identified a number of recreation uses in the Upper Arrow Reservoir. The most frequently ranked recreation uses included: dog walking, walking/hiking, nature viewing/bird watching, mountain biking, canoeing/kayaking, skiing, and fishing. These are primarily individual, unorganized activities.

A study prepared for the Revelstoke Community Futures Development Corporation (Future Legacy Consulting Group, 2000) examined recreation activities within the Columbia Forest District. Recreation activities identified by the study as occurring in the Upper Arrow

Reservoir included: camping (Blanket Creek Provincial Park), canoeing/kayaking (early April-October; with 80-90% of participation by local residents), fishing (flyfishing and spinning/casting from boats and shore; March-April; 80-90% locals), horseback riding (Airport flats; local residents), hunting (local residents), mountain biking (80% local riders), and power boating (May-October with higher use during summer months; 80-90% are locals; lack of a marina facility in Revelstoke identified as limiting use).

6.3 Conclusions

The revegetation program has had a positive impact from an aesthetic and recreation standpoint. According to many of those surveyed, the revegetation program has resulted in a more pleasant area and a positive recreation experience (less dust, more green areas) and some of those interviewed claim that the vegetation growth in the reservoir has led to an increase in birds, fish and other wildlife. In turn, this has led to an increase in recreation opportunities. People are more inclined to use the area for recreation because of these conditions. There is a general perception that the area is more desirable for recreation because of the vegetation growth. It should also be noted that many recreation activities are dependent upon water levels within the reservoir. When at low pool, a number of wildlife habitats are provided as well as trails and roadways. As the reservoir fills, these features are not available for use. However, some for some recreation activities such as flyfishing, canoeing and kayaking, opportunities are enhanced.

6.4 References

B.C. Hydro. 1999. *Recreation Opportunities Inventory*. Power Supply - Environment. Burnaby, B.C.

BC Hydro Research Services. 2001. *Upper Arrow Seeding and Recreation Study*. Vancouver, B.C.

Future Legacy Consulting Group. 2000. *Revelstoke Area Recreation Inventory - Columbia Forest District*. Revelstoke Community Futures Development Corporation. Revelstoke, B.C.

McPhee, Michael. 2002. *Group and Organized Recreation Activities in the Upper Arrow Reservoir Drawdown Zone*. Quadra Planning Consultants Ltd. Prepared for BC Hydro SEIP: Evaluation of Ancillary Benefits of Reservoir Shoreline Revegetation Project

R.L.&L. Environmental Services Ltd. et. al. 2000. *Environmental Information Review and Data Gap Analysis. Volume I: Upper Columbia, Mica and Revelstoke Projects. Draft Report*. Prepared for BC Hydro, Water Use Planning. Burnaby. B.C.

Waters, Lauren. 2000. Revelstoke Wetlands Conservation Area Feasibility Study. Prepared for The Illecillewaet Greenbelt Society. Revelstoke, B.C.

7.0 Conclusions

The SEIP project has contributed to an understanding of the complexities between reservoir operations and related vegetation growth, aquatic, wildlife, aesthetic and recreational interactions. The project was challenging and confirmed that careful thought must be given to study objectives, design and data collection methods. Research in active operating reservoirs is also a challenge because conditions can change rapidly (i.e., water levels rise). The study period was relatively short, field operations were restricted, and water levels from year to year were quite different. This created problems for study design, data acquisition and comparisons. In addition, there is relatively little experience in reservoir vegetation management that could be drawn upon for this project.

Despite these limitations, it is clear that several benefits from the reseeding program have resulted. Some are clearly visible and measurable. The vegetation mapping has developed a benchmark that will allow for future vegetation cover measurements. We have a better understanding of the interactions between water levels, plant growth, wildlife presence and aquatic productivity. There is potential for applying this research to further understanding of carbon accumulation in reservoir systems. It is also clear that recreational activities are an important component of reservoir operations and that the seeding program and native vegetation growth have contributed to the enjoyment of recreational pursuits in and adjacent to the reservoir.

This study has made a positive contribution to the broader resource management decisions that are part of Water Use Planning. Water Use Plans have direct implications for reservoir operations and through this study, information has been generated that will assist BC Hydro in further understanding the relationships between reservoir operations, and ecological and social functions and processes.

In summary, the value of this project has included:

1. Confirming the ancillary benefits of shoreline revegetation in the drawdown zone of the Upper Arrow Reservoir. These include:
    - increased aquatic biodiversity
    - provision of habitat and food for fish and wildlife
    - increased aquatic productivity
    - improved aesthetic benefits
    - additional recreational benefits
    - increased wildlife habitat diversity
    - increased opportunities for carbon sequestration

2. Creating a greater scientific understanding of interactions between reservoir operations (water levels), vegetation community development, elevations, nutrients and biomass production. This information is extremely valuable for transfer to other reservoir systems where the establishment of vegetation is an issue. In addition, the study generated an ecological model that demonstrates and explains these interactions. Subsequently, the

model was adapted for use in Water Use Planning in the Bridge-Seton, and Columbia River systems.

3. Producing a range of mapping products, GIS, Digital Elevation Model and other data for the Upper Arrow Reservoir that can be accessed by a wide range of users.

4. Opportunities for applying lessons learned and experimental design to other reservoirs, particularly in relation to dust control methods, vegetation establishment and monitoring, digital mapping, orthophotography, and ecological modelling.

5. Generating and disseminating comprehensive information for the public, reservoir managers and researchers (i.e., public and technical reports, databases and CD-ROM). The information has the capacity to be web-based for even greater distribution.

8.0 Recommendations

The following recommendations are extracted from the individual reports that were prepared as part of the project.

Vegetation, Soils Analyses and Vegetation Mapping
Carr Environmental Consultants and AIM Ecological Consultants Ltd. *Synthesis of Vegetation and Soil Studies For Revelstoke Reach - Upper Arrow Reservoir. May 2002.*

The revegetation program for the Upper Arrow drawdown zone has been a success not only in controlling dust generation, but also provided the basis for numerous spin-off benefits to the area generally associated with wetland development. Among these are increased recreational use, new wildlife habitat, and vegetation associated nutrient and carbon inputs into the aquatic environment. Efforts to expand this type of program within the BCH reservoir network have already begun at Williston Reservoir and Stave Reservoir, with the potential for expansion to other areas. As this type of program is unique in managed reservoir systems throughout the world, only the Upper Arrow program is currently available to provide long-term insight as to vegetation production and species development, as well as the influence of water regime management on wetland community establishment.

It has been only through both formal and informal monitoring of the Upper Arrow Dust Control Program over the past decade that BCH has been able to begin understanding the potential for vegetation establishment in drawdown zones. The plant community successional patterns have been shown to be sensitive to reservoir elevation and the dynamics of annual inundation, key factors affecting the future use of reservoir revegetation that need long-term study. Continued assessment of the soil/vegetation carbon pool may be warranted given the corporation's interest in acquiring carbon off-set credits. Other parameters associated with the new wetlands, such as biomass and nutrient distribution, provide important information on this new type of ecosystem and should be part of a long-term monitoring program if BCH wishes to contribute to the science of drawdown zone enhancement. The results from this program have contributed greatly to the development of the RESVEG ecosystem model (Korman, 2002) that is currently being used for impact analysis on several reservoir systems within the Water Use Planning program. Preliminary results from the model using Arrow data appear to address water inundation and duration impacts on vegetation establishment from an overview perspective. The current version of RESVEG provides an excellent starting point for comparisons of proposed water regimes and potential impact on reservoir littoral zone vegetation and revegetation options.

As of 2000, 434 m appears to be the lower boundary for extensive recolonization by wetland species, although this will be determined in the long run by reservoir operation. Several consecutive higher than average water level years will probably raise this lower limit, while several lower years may allow for extension of the permanent vegetation community to lower elevations. Reed canarygrass and lenticulate sedge are the two dominant wetland species throughout the permanently recolonized zone, with both species heavily influenced by reservoir elevation. The higher the elevation within the zone of recolonization, the more dominant reed canarygrass becomes and the lenticulate sedge goes from a co-dominant species to more of an understory species. The Columbia sedge is found in sporadic patches above 435 m, but has does not appear to compete well with the reed canarygrass at the higher elevations.

The growth performance of the vegetation in terms of biomass and nutrient status also appears to be sensitive to elevation change for all species. On a per unit area basis ($g.m^{-2}$), the lenticulate sedge is by far the highest biomass producer and highest net exporter of vegetation into the aquatic environment during inundation. Production of the reed canarygrass and Columbia sedge is similar, with the reed canarygrass's contribution to the ecosystem far greater due to its dominant presence throughout the area.

Both the airphoto assessment (AIM, 2001) and field sampling program undertaken in 2000/2001 have provided a test of methods that should be incorporated into a long-term monitoring program. Although the objectives of such a program will determine the specifics with regard to frequency of sampling and level of detail, the airphoto assessment appears to be a very cost-effective method for gathering information on vegetation community dynamics (change in composition and rate of spread) within this extensive area. The level of detail obtained from 1:5000 scale airphotos, especially after scanning and enlargement, allows for easy stratification of the area into vegetation associations that can be related to orthographic elevation data. Only limited field verification for confirmation of interpretation of more complex polygons is required by an experienced mapper, resulting in a relatively inexpensive assessment that will contribute significantly to BCH's understanding of vegetation community dynamics and the influence of water regime. This type of monitoring should be conducted on a periodic basis, at a minimum of every five years, or at an accelerated time frame in response to a major shift in water management that lasts for three years (at this time believed to be the threshold where significant changes in plant establishment and spread are realized).

The stratification of the vegetation communities using airphoto assessment is very important if (or when) a detailed assessment of biomass, nutrients, or soil parameters is required. The stratification will provide delineation of the detailed sampling units where the modified grid-point intercept method used in the 2000 field program can be applied. This type of approach will provide statistically valid determination of individual plant species presence and abundance within a specific plant community, key information to extrapolate subsequent data throughout the entire sampling area. Further detailed sampling of biomass, nutrients, or soil parameters should then focus on the dominant species found in each stratum.

The sampling procedures employed in this study are appropriate for detailed biomass (standing and root), plant and soil nutrient content, and carbon pool determination. The species specific sampling approach implemented in 2000 yielded biomass values that allowed for a clearer understanding of the contribution to production of the revegetated Upper Arrow drawdown zone for the vegetation communities as a whole and individual species performance and contribution. There are major differences not only in the distribution of the wetland species that have recolonized the drawdown area according to reservoir elevation, but also the amount of biomass produced by individual species within and across the elevation range (434 m - 437+ m) of permanent vegetation establishment. The effect of recolonization on soil development and carbon accumulation parallels, for the most part, the biomass patterns of the vegetation.

It is important for BC Hydro to clearly define the goals and objectives (as well as precision) of any future detailed sampling program because the cost of laboratory analysis can be considerable. The number of samples to be taken for each species and design of statistical analyses will be determined by the objectives and desired level of precision.

Biofilm, Invertebrate and Fish Communities

Limnotek Research and Development Inc., RL&L Environmental Services Ltd. and Eco-Logic Ltd. *Biofilm, Invertebrate and Fish Communities Associated With Vegetation Strata in the Drawdown Zone of the Arrow Lake Reservoir. Final Report.* October 2001.

While this study was a major step forward in examining potential benefits to the aquatic community to revegetation of a drawdown zone, other tasks can be considered to measure longer-term benefits. Examples are as follows:

- Sampling of lower trophic levels in 1999 followed development of the benthic community over a relatively short period of up to 78 days. In this time period, an abundant fauna was found. Animals were small, however, making them largely unavailable to visual predators. If the opportunity arises to repeat the 1999 experiment, it should include a longer period of sampling to determine if advanced development of the benthic community produces larger individuals and greater biomass than was found in 1999. Larger animals would potentially increase their availability to fish late in the growing season and increase the importance of vegetation establishment as a benefit to fish populations.
- Most surface depressions in the drawdown zone of Revelstoke Reach become dewatered as the water surface elevation of the reservoir declines in winter months. Many fish can be stranded in those depressions and pools as water recedes. In winter, ice forms over these pools but under the ice the water can recede to ground by infiltration, leaving a dry depression in most circumstances. The result is that all fish die that are stranded. Through winter, otter and birds of prey have been observed to dig passages under the ice or through the ice to feed on the fish carcasses and perhaps other organic matter left there from the previous growing season. The result is that either no carcasses remain in the spring or numbers are greatly diminished over what they were at the time of drawdown. These local observations suggest that fish stranding may be closely linked to use of the drawdown zone by wildlife. For this reason, it may be important to link measurements of use of vegetated and non-vegetated areas by wildlife at different times of the year with measurements of fish stranding and total biomass produced in vegetation strata. Beach seining and electroshocking could be used to recover and enumerate newly stranded fish as soon as a series of pools are isolated from the reservoir at the start of drawdown in the early winter. Plant and benthos biomass estimates and measures of composition could also be completed at the same time. Thereafter, standardized surveys could be used to routinely observe use of pools by wildlife, stratified by type of vegetation that was characteristic of the sites in summer (barren, fall rye, mixed grasses). Measurements of

wildlife use could include direct counts of animals observed entering and leaving holes in the ice. They could also include counts of animal sign and analysis of scat to confirm direct feeding on fish by wildlife. These observations should ideally be conducted throughout winter by individuals having knowledge of wildlife sign and wildlife behaviour in the Arrow drawdown zone.

- A potential benefit of vegetation establishment in the spring months is that new and existing biomass may provide extensive habitat for terrestrial invertebrates. While these animals may directly provide food for birds, they may also be trapped with rising water later in the spring and summer. If this process happens, a pulse of food may be available for fish that follow the rising water into Revelstoke Reach. Evidence of the extent of this food supply may be measured with emergence traps or other sampling device capable of catching flying insects at the water surface. If there is interest to continue investigation of potential benefits to fish from revegetation of the drawdown zone, these measurements should be considered as part of future sampling activities.
- A potential consequence of vegetation establishment in drawdown zones is creation of a carbon sink. That sink may be in the form of permanent vegetation and associated soils or if plants die under water, it may be in the form of carbon taken up in vegetation and then translocated to the aquatic ecosystem to be fixed in other organic matter. Either of these processes or the combination of these processes may represent a significant carbon sink. Creation of large carbon sinks is desirable as a means to limit carbon loss to the atmosphere. The magnitude of such a sink may be determined with calculation of a carbon budget for the aquatic component of the Revelstoke Reach in which the fate of downstream transport of carbon is measured. These data may be coupled with existing work on development of a carbon budget for soils of the Revelstoke Reach.

Wildlife

Songbird Survey

Boulanger, John, John G. Woods and Janice Jarvis. *Songbird Use of Four Floodplain Vegetation Types in the Revelstoke Reach, Upper Arrow Reservoir, British Columbia, Canada.* April 2002.

1. Repeat these surveys during years with varying water conditions (e.g., “normal” years and “high” water years). The survey sites identified in 2001 could be used as base points for future sampling.
2. Investigate the relationship between water levels, vegetation types, and bird forage production.
3. For selected species, determine whether these reservoir habitats constitute “source” or “sink” populations.
4. Attempt to sample more cottonwood and willow plots. Use of different numbers of plots complicates the comparison of species richness and species diversity of different areas. Therefore, if possible, the sample size of plots for each habitat type should be made more even. Alternatively, there are potential randomization methods to further account for uneven sample sizes between plots when assessing species diversity measures.
5. Consider the use of distance methods if particular target species are of interest. Distance methods allow more robust estimation of species density. This method is much better

suited for individual species rather than whole bird community analysis. The results of this study can be used to assess whether sample sizes are adequate to use distance methods for species of interest.

6. Consider the measurement of other covariates besides habitat type, which might affect species diversity and abundance. Other covariates such as water levels, elevation, the stage of vegetation (i.e. leaf cover), and potentially insect abundance may allow further explanation into differences between habitat types. The actual choice of covariates to measure should be based upon knowledge of factors that affect bird abundance.
7. Consider estimation of movement of species between habitat types. It is possible to further extend the Pradel demographic analysis to estimate movement rates of species between habitats as a function of water level or spring green up of habitat types. For example, if multiple surveys were conducted at various water levels then it would be possible to determine if bird species move to different habitat types as a function of water level. Or, it may be possible that species initially utilize the cottonwood and willow habitat types prior to green-up of the grass stands. In this case there would be little movement of species until later periods in the survey. Using multi-strata models in program MARK (White and Burnham 1999) it is possible to estimate movement rates between habitat types to determine how the habitat types might relate to each other temporally in the migration and nesting seasons or as a function of water level. This analysis should be based upon a-priori hypothesis of movement, and was beyond the scope of the efforts presented in this manuscript.

Migratory Bird Monitoring

Jarvis, Janice. *Columbia River-Revelstoke Migration Monitoring Station Final Banding Report For 2001.* 2002.

1. The CRR station has completed 4 successful years of fall migration monitoring with the completion of the 2001 season. The CRR station located in a functioning reservoir has many challenges associated with operating a migration monitoring station. The past 4 years have seen various water levels from high (1999/2000) to low (2001); even-though the station may be subject to flooding and potentially reducing the amount of days and nets used in a season this location is still the first choice for a migration monitoring station on this stretch of the Columbia River. A protocol for the station should be submitted to the CMMN for review with changes being made during the 5th season during the fall of 2002.

2. The Revelstoke Reach wetland in which the CRR station is located is unique system not only on the Columbia River from Donald to the Pacific Ocean but perhaps throughout North America. The vegetation that is the vital component of this area is unique in its ability to survive the inundation of a reservoir system. The increased knowledge of the various flooding regimes, vegetation, wildlife and fish will not only facilitate better resources understanding but also have the potential copied elsewhere.

3. The use of the area by landbirds must co-exist with reservoir operations, wildlife, fish, and recreational use. The data collected at the station is currently being used for the 'Water-Use Plan' for the Columbia River to look at future operations of the dams to

avoid or reduce threats to migrating landbirds. The data gathered at the station will provide local residents and land-use managers a better understanding of the landbirds use and needs over time.

Waterbirds
Jarvis, Janice and John G. Woods. *Waterbirds of the Revelstoke Reach Wetlands, Upper Arrow Reservoir, Revelstoke*, British Columbia, Canada. June 2001.

1. The Revelstoke Reach wetlands are unique in the Columbia River system from Donald to the Pacific Ocean and are the only known major area used by waterbirds within the Columbia River system of impounded waters. Increased understanding of the interplay of flooding regimes, vegetation, wildlife, and fish in this area would enhance our ability to predict changes under different management regimes in the future. This database has been developed as a tool to facilitate resource understanding in the upper portions of the Upper Arrow Reservoir.

2. Within the Reach, the wetlands inside the Revelstoke Airport runway are the most significant in terms of waterbird use, both in terms of species richness and individual abundance. Opportunities to create similar ‘pocket’ wetlands may exist elsewhere on the reservoir system..

3. Waterbird and use of the Reach must co-exist with reservoir operations and recreational use of the area. The maintenance of an accessible data base on this resource will assist water-use and land-use planners. We recommend that steps be taken to ensure that long-term monitoring continues and that the resulting data be widely accessible.

Ecological Modelling
Korman, Josh. *Simulating the Response of Aquatic and Riparian Productivity to Reservoir Operations: Description of the Vegetation and Littoral Components of BC Hydro’s Integrated Response Model (IRM).* December 2002.

A key objective for any modeling exercise should be to expose data gaps and uncertainties in the processes that are being modeled. For many ecological models where data is limited and uncertainties are high, the benefits of meeting this objective often outweigh the utility of being able to make quantitative predictions about various policy alternatives such as water level management and planting. The development of the vegetation model for the Revelstoke Reach of the Upper Arrow Reservoir was very helpful in differentiating what we know about this system from quantitative and qualitative perspectives. While monitoring on this system has been conducted since the early 1990’s and many numbers have been collected, our quantitative understanding on how vegetation has changed over time, and the response of this vegetation to inundation and fall rye planting, is quite weak. Section 4.1 provides a set of recommendations for improving future monitoring efforts based on the problems identified in the development of the vegetation model.

Development of a computer model is a continual process. As our understanding improves and more data becomes available over time, model structure and parameters can be refined to make better predictions. The review process of this document has identified improvements to model parameters that should be implemented in the next application of the model. Section 4.2 summarizes these improvements.

Monitoring Recommendations

A vegetation monitoring program should track changes in vegetation and seedling establishment over time, and help establish key relationships between survival, growth and various management practices such as planting and water elevation schedules. Quantifying of changes in vegetation is most important component of the monitoring program and should be accomplished by repeat sampling of plots and interpretation of aerial photographs. The selection of sampling plots should be based on a random-stratified design with the strata being defined by key variables that control the establishment, growth, and survival of vegetation (elevation, fall planting intensity, substrate, aspect). It is very important that these plots cover the potential range of elevations that could be colonized by terrestrial plants (and submerged marcophytes if appropriate). It is also important that sampling plots be established in areas that receive a range of fall rye planting intensities. Sampling should be conducted on a monthly basis from the start of the growing season, and all elevations that are not inundated should be sampled on each monthly period. Parameters to be measured at each sample plot should include cover, biomass (of roots and shoots), mortality of mature plants, and some index of seedling establishment. Measures of cover should be consistent across vegetation groups. Using different methods to estimate cover for different vegetation groups introduces unnecessary complications and error into any subsequent analysis. Plot boundaries should be spatially referenced to a reasonable degree of horizontal accuracy (+/- 2-5 meters) to assist in the interpretation of aerial photographs.

The interpretation of aerial photographs will provide a system-wide estimate of vegetation change over time. A DEM for the monitoring area should be developed and color photographs taken at a pre-determined intervals (e.g. every 3 yrs). The photographs for the DEM should be flown when the water surface elevation is at its lowest, usually in the early spring. For vegetation monitoring, the photographs should be taken early enough in the year to document before vegetation at lower elevations is flooded, but not too early so that vegetation has not had sufficient time to green-up. Ideally, field sampling of plots should be conducted close to the time air photographs are taken to assist in the interpretation. Analysis of the photographs should be based on modern image-processing techniques. The photographs should be rectified so they can be overlaid on the DEM. Algorithms should be developed to predict vegetation community structure and cover based on the color and intensity of each pixel. Such an approach would avoid problems encountered by AIM (2002a) where polygons classified as ‘incipient vegetation’ contained large areas of barrens substrate, resulting in substantial overestimates in the amount of vegetation cover. Plot data should be spatially linked to the photographs to develop the interpretation algorithms.

The development of the aerial photograph interpretation methods is a substantial task and should not be underestimated. The level of resolution at which these algorithms can predict community structure and cover is uncertain. It may be that manual interpretation is the only way to estimate community structure with any reasonable degree of resolution (e.g., AIM

2002a). In this case, a stratified random subsample of the total area covered by the aerial photographs will likely be required. The stratification should follow the same delineation developed for monitoring the plots. A combination of manual and automated interpretation should be explored. For example, community structure for plots could be estimated manually, with cover estimated by a computer algorithm.

The monitoring program should contain an experimental component that allows estimation of certain model parameters that could not be achieved by the monitoring activities described above. Quantifying the effects of inundation on survival and growth of seedlings and mature plants could be accomplished by experimental planting at a range of elevations. These areas would be sampled over the growing season to determine the proportion of seedlings and mature plants that died under different inundation conditions (duration and depth) and how their growth was affected. Similar experiments could be conducted to estimate the effects of dry stress. The feasibility of performing these experiments in the field should be compared to the feasibility and utility of performing them under more controlled conditions that could be attained in a greenhouse.

The bounds of the monitoring program should be carefully defined. The lateral and elevational extent of the monitoring area should include not only areas that are currently vegetated, but also include barren areas that have the potential to recover under conceivable planting and water management schedules. The types of vegetation to be monitored should be based on not only their dominance in the current community, but also on their importance to wildlife. There was virtually no monitoring of cottonwoods or woody shrubs (e.g., willow) in the Revelstoke Reach monitoring program, yet these vegetation groups are influenced by dam operations and very important to wildlife. A similar argument can be made for wetland species. The design of a vegetation monitoring should consider the needs of other programs. For example, if mammals and birds are monitored, ensure that the types of variables collected by the vegetation program are useful in the interpretation of the mammal and bird data. This argument is also relevant for linkages with aquatic productivity or fish population monitoring programs.

Modelling Improvements

Refinements to vegetation model parameters affecting seedling establishment were suggested by W. Carr and A. Moody. A summary of these changes is presented in the table below. A structural change to the seedling establishment component of the vegetation model was also suggested. The maximum number of flooded weeks that seedlings can tolerate will change according to the age of the seedlings (A. Moody, pers. comm.). The original values used in this modeling exercise (5 wks for most groups) are potentially too high for very young seedlings and too low for older seedlings. In general, seedlings less than one month old cannot tolerate any inundation and those greater than 3 months can tolerate inundations of up to 8 weeks. This dynamic could be simulated in the model by developing a functional relationship between the age of the seedling and the maximum wet stress that it can tolerate. While this improvement could be easily made, it should be noted that we have no data to tune or test the seedling establishment component of the vegetation model. Predictions of seedling establishment are highly uncertain, and increasing model complexity will not reduce this uncertainty.

Refinements to vegetation model parameters that should be implemented for future applications of the vegetation model.

Parameter Description	Parameter Name	Vegetation Group	Original Value	Refined Value
First week of seedling establishment period	SeedWkMin	Fall Rye	28	16
Last week of seedling establishment period	SeedWkMax	Fall Rye	42	36
Number of consecutive weeks required for seedling establishment	SeedWks	All groups	5-10	8
Crown cover following seedling establishment	SeedIniCover	All groups	5	1
Maximum tolerable dry stress for seedlings	SeedMaxDryStress	All groups	600-1000	Higher values

A significant improvement to the littoral production model was suggested by C. Perrin (Limnotek Research and Development Ltd., Vancouver, B.C.). Benthos biomass at any one-meter elevation slice is the sum of barren substrate biomass and biomass on the roots and leaves of vegetation (eqn. 11). Benthic biomass in barren substrate is assumed to be independent of the inundation period. Perrin pointed out that this assumption in valid in barren substrate at lower elevations that are not surrounded by plants. At higher elevations, very little barren substrate was observed, and benthic biomass increased with inundation time, presumably in response to increased benthic biomass on plants adjacent to the barren substrate. To simulate this dynamic the following changes to the littoral model should be made. First, the amount of barren substrate for each one-meter elevation slice ($Area_{barren}$) should be computed as,

$$Area_{barren} = TotalArea * (1 - \sum_{i=1}^{MaxVegTypes} prop\_co) \tag{13}$$

where, *TotalArea* is the total area of the elevation slice and *prop_co* is the proportion of cover for each vegetation group at that model timestep. In cases where the total cover across all vegetation groups exceeds 1, no barren area will be present. The benthic biomass for this remaining area ($BenBio_{barren}$) would then be predicted based on the number of days since inundation (t) by the equation,

$$BenBio_{barren} = 4.33 * 10^{0.016*t} \tag{14}$$

The total benthic biomass for barren areas for any elevation slice is simply the product of the barren area (eqn. 13) and the unit area-biomass of this area (eqn. 14).

Aesthetic and Recreation Benefits
McPhee, Michael. *Group and Organized Recreation Activities in the Upper Arrow Reservoir Drawdown Zone*. March 2002

- Recreation use of the revegetated areas should be monitored to ensure there is no damage to the established and newly established vegetation.

- Management of recreation uses may be required to ensure that sensitive wetland and wildlife areas are not impacted. This could involve establishing formal pathways or routes that avoid sensitive areas and limiting access in some areas or periods (e.g., bird ground nesting sites and seasons)

Appendix 1: Digital Products

GIS, GPS and Aerial Photography Products - Upper Arrow Revegetation Benefits Program Current to: March 2003

Projection and Datum for all digital GIS data: UTM Zone 11, NAD 83

	Product type	Description	Extents	Format(s)	Comments
BASEMAP DATA					
1	Orthophotos	B&W 1:5,000 - photo date June 4, 2000	Revelstoke Dam to Shelter Bay	18 .tif files, hardcopies	BCH digital license agreement required for contractors
2a	Airphotos	B&W 1:30,000 May 9, 1968	Revelstoke Reach	hardcopy prints	
2b		Color 1:20,000 Aug. 7, 1977	Revelstoke Reach	hardcopy prints	
2c		B&W 1:10,000 Apr. 12, 1991	Revelstoke Dam to Shelter Bay	hardcopy prints	
2d		Color 1:5,000 May 24, 2000	Revelstoke Dam to Tank Creek	hardcopy prints	
2e		B&W 1:10,000 May 24, 2000	Revelstoke Dam to Shelter Bay	negatives	
2f		B&W 1:25,000 June 4, 2000	Revelstoke Dam to Shelter Bay	negatives	
3	Airphoto Flight Lines	GPS photo centres for 2000 flights	Revelstoke Dam to Shelter Bay	ArcView shapefiles	
4	Digital Elevation Model (DEM)	10 m grid (masspoints) + breaklines + spot heights	Hwy 1 bridge to south of Akolkolex River	ASCII x,y,z file; ESRI GRID	BCH digital license agreement required for contractors
5	Contour lines (drawdown zone)	1m intervals (429-440 elevation)	Hwy 1 bridge to Tank Creek (between Akolkolex R. and Arrowhead)	.dgn files; merged and converted to ArcView shapefile	
6	TRIM data	Selected streams, selected roads, reservoir edges and dam footprints used for cartographic maps	Sheets: 82K.061, 82K.071, 82K.080, 82L.090, 82L.099, 82L.100, 82M.009, 82M.010	ArcInfo coverages; selected elements as ArcView shapefiles	BCH digital license agreement required for use by contractors
GPS DATA					
7	Songbird point count plot centres	Differential GPS coordinates - submetre accuracy	Revelstoke to Drimmie Creek	ArcView shapefile (point)	GPS data collected June and July 2001, bird surveys conducted May-July 2001
8	Vegetation transplant & monitoring plots	Differential GPS coordinates - submetre accuracy	Revelstoke airport (Area G) to Drimmie Creek (Area P)	ArcView shapefiles (centre points and plot polygons)	GPS data collected June 2001
9	Waterfowl survey observation points	Differential GPS coordinates - submetre accuracy	Illecillewaet River to "9 mile" (Area M)	ArcView shapefile (point)	GPS data collected June and July 2001
10	Access roads in drawdown zone	Differential GPS lines	Revelstoke airport (Area G) to Drimmie Creek (Area P)	ArcView shapefile (line)	GPS data collected June and July 2001

	Product type	Description	Extents	Format(s)	Comments
PROJECT-SPECIFIC GIS DATA					
11a	Aquatic sampling sites	Water Chemistry Sites	S. of Revelstoke Dam to N. of Arrowhead	ArcView shapefile (point)	Approximate locations based on hand-drawn locations on field maps
11b		Fish gillnet sites	S. of Revelstoke Airport to Cranberry Creek	ArcView shapefile (point)	Approximate locations based on hand-drawn locations on field maps
11c		Fish electroshocking transects	S. of Begbie Cr. to Crawford Cr.	ArcView shapefile (line)	Approximate locations based on hand-drawn locations on field maps
11d		Underwater video transects	Walter Hardman powerhouse to Cranberry Creek	ArcView shapefile (line)	Approximate locations digitized based on hand-drawn locations on field maps
11e		Vegetation outplanting sites	Walter Hardman powerhouse to Crawford Creek	ArcView shapefile (polygon)	Approximate locations digitized based on hand-drawn locations on field maps
12a	Recreation routes	Birdwatching, horseback riding & jogging routes used by organized groups & clubs in the drawdown zone	Revelstoke to Montana Slough	ArcView shapefiles (lines)	Generalized routes based on interviews with local residents
12b		Shoreline, troll and fly fishing; boat launches	Revelstoke to Shelter Bay	ArcView shapefiles (lines and polygons)	Generalized areas based on interviews with local residents
13	Soil analysis sites	Grid point intercept survey sites	Revelstoke Airport (Area G) and Drimmie Creek (Area P)	ArcView shapefile (point)	Approximate location of transect hubs. Digitized by measuring distances from GPS coordinates of stakes
14	Vegetation mapping	Polygons of major vegetation groups based on interpretation of 1968, 1977, 1991& 2000 airphotos	Revelstoke Airport (Area F) to S. of Mulvehvill Cr. (Area T)	ArcView shapefiles (polygons)	Digitized polygons from hardcopies of airphoto interpretation results rectified to orthophotos
15	Vegetation bands by elevation	1 m elevation bands and major vegetation classes	Revelstoke Airport (Area F) to S. of Mulvehvill Cr. (Area T)	ArcView shapefiles, Excel spreadsheet	used in Josk Korman's Integrated Response Model (IRM)
16	Dust control areas	BC Hydro dust control polygons - very generalized boundaries	Area E (Illecillewaet River) to Area Y (Cranberry Creek)	ArcView shapefile (polygon)	Very generalized polygons digitized around vegetation mapping areas; for cartographic display only Not suitable for legal descriptions or analysis

CARTOGRAPHIC MAPS

17	PDF maps	All maps in the overview report and individual contractor reports are available in 2 resolutions: screen (150 dpi) and print (300 dpi)	Adobe portable document format (PDF) files.
OTHER GIS PRODUCTS			
18	ArcView 3.2 project files	ArcView project files with map layouts were created for: study area overview, aquatic sampling, songbirds, recreation, soil and vegetation analyses, vegetation mapping	.apr files with map layouts, associated shapefiles, legend (symbology) files

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