# Synthesis of Vegetation and Soil Studies For Revelstoke Reach – Upper Arrow Reservoir

May 2002

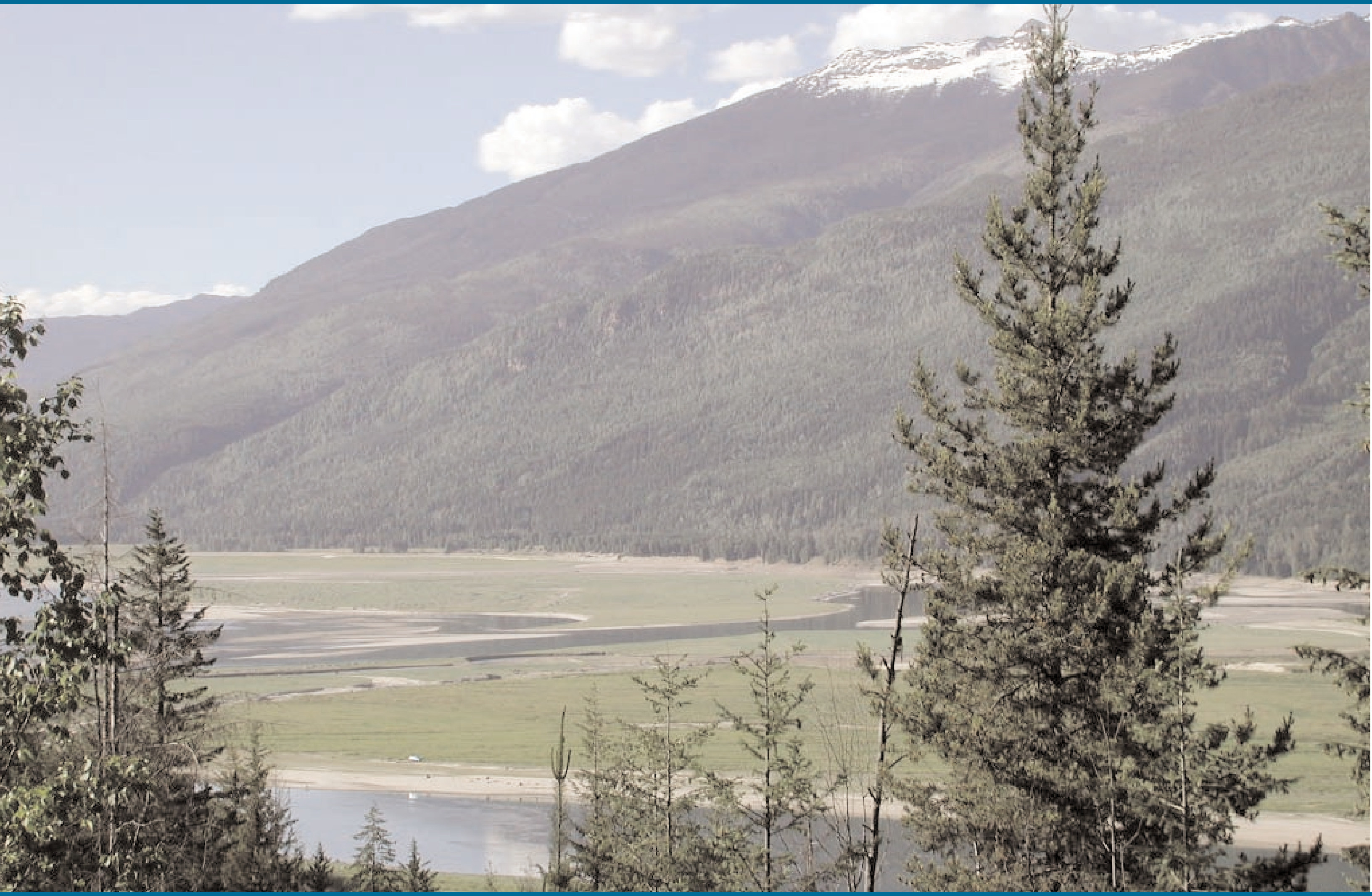

*Photo courtesy of Wendy Beauchamp*

*Prepared by:* CARR Environmental Consultants and AIM Ecological Consultants Ltd.

*Prepared for:* BC Hydro Strategic Environmental Initiatives Program
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 Program**

# Synthesis of Vegetation and Soil Studies

# For

# Revelstoke Reach - Upper Arrow Reservoir

*Prepared by:*

**CARR Environmental Consultants.**
**and**
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# Abstract

Since the late 1980's, significant portions of the Revelstoke Reach of Arrow Reservoir have been repeatedly seeded with fall rye for wind erosion control and dust abatement. 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.

An objective of the BC Hydro Strategic Environmental Initiatives Program (SEIP): 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. In 1999, BC Hydro initiated an evaluation of the potential benefits associated with the new wetland area under the SEIP Program.

Due to limited information regarding the permanent vegetation within the dust control areas, a two year field program was initiated in 1999 to quantify the distribution and abundance of native vegetation. A grid-point intercept sampling system was utilized to document vegetation community composition. A stratified sampling system was used to assess soils and to determine above and below ground plant biomass and nutrient data. Aerial photographs obtained in 2000 were used for detailed mapping of the native vegetation within the study area and to create a digital terrain model used in the GIS analysis.

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. As of 2000, 434 m (6 meters below full pool) appears to be the lower boundary for extensive recolonization by wetland species. However, newly developing vegetated areas were noted extending to 432 m. Several consecutive higher than average water level years will probably raise the lower limit of plant growth, while several lower years may allow for extension of the permanent vegetation community to lower 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.

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.

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.

## TABLE OF CONTENTS



## LIST OF TABLES

# 1 INTRODUCTION

## *1.1 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 were 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:

- Seeded annual fall rye (primarily at elevations <434m)
- Sedge dominated communities, including other wetland species (extending from 433 to 436 m)
- Reed canary grass community, including an understory of wetland species (extending from 434 to 436+m)
- Horsetail dominated communities (occurring primarily at 435+m)

Over the latter half of the 1990's, there have 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 (Figure 1). The development of extensive areas of vegetation within the reservoirs has the potential to affect both the aquatic and 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.

## *1.2 Objectives*

Three major objectives have been identified within the Reservoir Vegetation Studies component of the Upper Arrow Reservoir Revegetation Strategy program:

- 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
- 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
- to develop tested data inputs for the RESVEG ecosystem model (Korman, 2002) for linking vegetation to reservoir habitat values

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

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

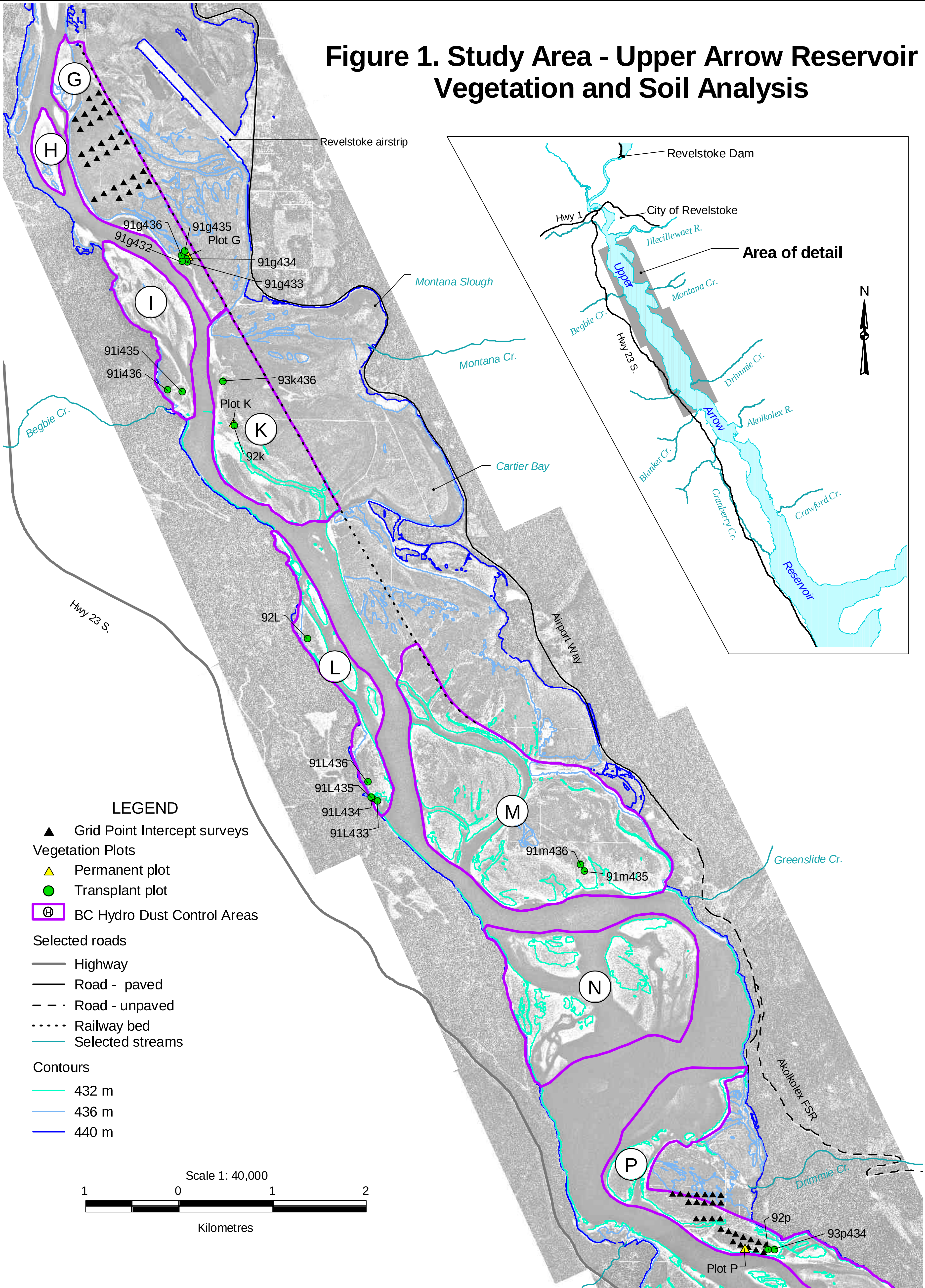
The field study was a cooperative program between CARR Environmental Consultants, AIM Ecological Consultants Ltd., and Pacific Soil Analysis Ltd. The first two years of the program, 1999 and 2000, focused on the sampling of above-ground and below-ground biomass of the permanent vegetation cover for quantification 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 undertaken by year and analysis results are presented in the following:

- 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)

# Figure 1. Study Area - Upper Arrow Reservoir Vegetation and Soil Analysis




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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# 2 APPROACH

## *2.1 Field sampling of vegetation and soils – 1999 and 2000*

At the inception of the project, there was limited information on the extent of development of the permanent vegetation associated with the dust control areas. The first year field program was viewed a pilot study to quantify preliminary information on the vegetation community that had established, and provide a basis for future field programs. In May/June 1999, an extensive pilot study was conducted throughout four of the largest areas of native recolonization within the area of interest; i.e. former dust control areas G, K, M, and P (refer to Figure 1). A key outcome of the pilot study was modification of the sampling design to be more species specific in the vegetation and soil sampling instead of using an aerial cover approach. In the 1999 pilot study, vegetation and associated soil sampling used randomly selected 0.5 $m^2$ plots which contained highly variable plant community combinations of the various species that occur throughout the permanently vegetated area (limited to the upper 5 m of the drawdown zone). Although effective for the pilot study, a decision was made to attempt to reduce the variability in the biomass and nutrient estimates through a combination of species specific sampling and quantification of the proportion of each species in the plant community.

It was also evident after the first year that the permanently vegetated area was dominated by reed canarygrass and lenticulate sedge. Other species such as horsetail, Columbia sedge and numerous annuals were also present, although occupying a more minor percentage of the area cover. Fall rye, initially a species of interest, was deemed to be a major species only in those areas below 435m in elevation which were seeded annually and not contributing significantly to the permanent vegetation community. The decision was made to concentrate only on key contributors to the long-term ecosystem benefits within the drawdown zone, and fall rye was dropped from the field sampling program.

Two major changes were made in the field sampling program for 2000 as a result of experience and results from 1999. The first was the implementation of a vegetation community survey program based on a modification of the grid-point intercept sampling system originally designed for soil disturbance surveys by the Ministry of Forests (Min. of Forests, 1997). This approach combines a systematic grid sampling regime with a random sampling of 60 points at each grid point to define the composition of the vegetation throughout the sampling area. At each point, the vegetation species (individual or combination) encountered is recorded, with the frequency of occurrence results assumed to be a surrogate for defining the percent composition of the vegetation community by species. This approach provides a statistically valid, repeatable survey method to address the diversity in growth form and habit of the various species encountered throughout the area of interest.

The grid-point intercept sampling system also provided the basis for more specific species biomass and nutrient sampling, the second major change. The area based sampling (0.5 $m^2$ plots) utilized in 1999 resulted in a high degree of variability in the biomass and nutrient data because the composition of the vegetation community has a high degree of patchiness (inconsistency) in vegetation cover on an area basis. This was a particular problem with the caespitose (i.e. clump-like) growth form of lenticulate sedge which is not evenly distributed throughout the vegetation community. In the 2000 field program, focusing on the percent composition of the plant community and conducting the biomass and nutrient analysis on a basis of homogeneous pure species samples over the entire 5 m elevation range reduced the overall variability in the data.

Although the 2000 field sampling program proposed to address the entire scope of the vegetation community that had established as a result of the dust control program at end of this section), scheduling delays combined with a rapidly rising reservoir severely limited the availability of area for field sampling. Access to much of the area was prohibited due to high water levels and the decision was made to focus on Area P (which encompassed the full range of target elevations), with additional areas added as access permitted. Only Area G (predominately 436m+) was accessible after the sampling of Area P. However there was a minor drawdown of the reservoir in mid-September 2000 which allowed for post-inundation sampling of portions of Area P and G, and thus the program's first direct assessment of the impacts of seasonal inundation.

## *2.2 Airphoto mapping to DTM - 2001*

In 2001, AIM Ecological Consultants undertook an airphoto interpretation exercise to identify, map and quantify the distribution of different vegetation types within the study area based on current and historical aerial photographs. This project addressed all of the permanent vegetation that had established as a result of the seeding program, much of which was not sampled in either 1999 or 2000. However, as confirmed by field verification of the mapping conducted in 2001, the vegetation and soil data (particularly that from 2000) can be extrapolated to the entire area of interest based on similar plant community composition (dominant and/or co-dominant species) and characteristics (vegetation density).

In addition to the determination of the vegetation community that has developed since 1990 through the expansion of the dust control seeding program, AIM also reviewed earlier pre- and post-reservoir creation airphotos. This review of 1968, 1977, 1991 and 2000 airphotos allowed for an assessment of the impact of initial inundation from impoundment on existing floodplain vegetation and the level of natural recolonization without (pre-seeding) and with (post-seeding) intervention by BC Hydro. Unfortunately the lack of suitable airphotos for the post-seeding period (1990 – present) precluded any evaluation of the rate of development for the permanent vegetation community that has developed as a result of the dust control seeding.

The time sequence mapping program was coordinated with the development of a new digital terrain model (DTM) for the Revelstoke Reach of Upper Arrow Reservoir. This new database, which also includes new orthophotos, not only provides an excellent basis for long-term monitoring of the development of the vegetation community, but also correlation of other ecosystem benefits (or attributes) that have been (or will be) evaluated on this area. A concurrent study on the utilization of the vegetated areas by songbirds demonstrates the potential of the combined vegetation mapping and DTM database for monitoring purposes.

## *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) 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.

# 3.0 OVERVIEW OF RESULTS

## *3.1 Key field study results*

The field studies undertaken under this program 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 are as follows:

- 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.

### 3.1.1 Species composition of the permanent vegetation community

A summary of the results of the grid-point intercept field survey of vegetation cover is presented in Table 1 for areas P and G. The sum of the percent cover in both areas is greater than 100% due to the presence of co-dominant or multi-species plant communities within the areas. Although both areas are dominated by reed canarygrass and, to a lesser extent horsetail, there are significant differences in species frequency between the two areas due to elevation range. Area P, which has an elevation range 434 - 437+ m, has a higher percentage of lenticulate sedge coverage and less reed canarygrass than area G. This probably reflects a higher tolerance and performance of the lenticulate sedge in the lower elevation areas of area P which are subject to greater inundation depth and periods. This ability of the lenticulate sedge to thrive with three and four meters of inundation in the reservoir was evident from planting trials conducted by AIM in the early 1990's (AIM, 1998).

Reed canarygrass is far more dominant over the limited elevation range (436 - 437+ m) at area G, reflecting a more aggressive and competitive growth capacity at higher elevations. In environments that are optimum for reed canarygrass growth, i.e. short periods of inundation and limited competition, it tends to form a monoculture, suppressing the growth and colonization of other wetland species. Although there is a minor component of lenticulate sedge and some other wetland species, it appears that the combination of water regime and elevation in the portion of area G sampled is approaching optimal conditions for reed canarygrass dominance. The lenticulate sedge, which was shown to grow well at higher elevations in the earlier plant trials (AIM, 1998), appears to be suppressed by the vigorous growth of the reed canarygrass.

**Table 1: Frequency of occurrence for plant species on areas P and G**

| Area | Reed canarygrass | Lenticulate sedge | Horsetail | Other species** | Bare |
|---|---|---|---|---|---|
| P (434+ m)<br>(95% C.I.)* | 65%<br>(± 8%) | 28%<br>(± 7%) | 34%<br>(± 10%) | 20%<br>(± 11%) | 8%<br>(± 4%) |
| G (436+ m)<br>(95% C.I.)* | 86%<br>(± 7%) | 10%<br>(± 4%) | 39%<br>(± 11%) | 13%<br>(± 7%) | 2%<br>(± 1%) |

* Denotes 95% confidence interval based on 29 GPI for P and 30 GPI for G.
** Other species encountered, listed in Table 1 of the 2000 data report, are primarily small annuals.
*** Frequency of occurrence is used as a surrogate for % coverage, and is referred to as % coverage in the remainder of the report.

Overall, in the opinion of the authors, the modified GPI survey approach proved to be an effective technique for determining vegetation cover composition. It is very suited for the patchy, sporadic establishment pattern of the sedges and other wetland species found in conjunction with the more continuous reed canarygrass stands. The sampling system was relatively quick to undertake, can easily be repeated on a periodic basis, and provides quantitative data on species density that can be monitored over time. The results from this type of survey can complement other analyses performed using airphotos (AIM, 2002) and modeling (Korman, 2002).

### 3.1.2 Plant biomass

#### Species effects

The species specific sampling approach used in 2000 allowed for a clearer understanding of the contribution of individual species to overall vegetation production in the Upper Arrow drawdown zone. Analysis of the June 2000 standing biomass data for area P, which unlike the sampling in area G spanned the entire elevation range of interest, revealed significant differences on an area basis (per $m^2$) between all species except between Columbia sedge and reed canarygrass (Table 2). The lenticulate sedge, with its dense, caespetose growth form, was by far the highest biomass producing species with a mean shoot AFDW of 2150.7 g/$m^2$. This species accounts for approximately 28% coverage of area P, but dominates the total shoot biomass (7.63 t/ha) on a per hectare basis at 73.0%.

Although shoot biomass production for both of the rhizomatous species (i.e. reed canarygrass and Columbia sedge) did not significantly differ between the species on an area basis, there was a general trend for the Columbia sedge to have higher production per $m^2$ at each sampling site. However with a 65% area coverage, the reed canarygrass is a significantly more important contributor to overall biomass at 23.8% than the more sparse Columbia sedge at this time. Horsetail, which occupied 34% of the area in either pure stands at the lower elevations of area P or as an understory in the higher elevations is a very minor contributor of biomass to the ecosystem.

**Table 2: Summary of June 2000 standing biomass (g/m2 AFDW) for area P by species, averaged over the 435 m – 437+ m, and contribution per hectare (t/ha) based on coverage from Table 1.**

| Biomass | Reed canarygrass | Lenticulate sedge | Columbia sedge | Horsetail |
|---|---|---|---|---|
| Species total/$m^2$ | 280.4 g/m2<br>b * | 1988.7 g/m2<br>a | 453.9 g/m2<br>b | 66.0 g/m2<br>c |
| Species total/ha (based on coverage)** | 1.82 t/ha | 5.57t/ha | 0.02 t/ha | 0.22 t/ha |
| % contribution (based on total/ha) | 23.8% | 73.0% | 0.3% | 2.9% |

* within row, values with different letters are statistically different using ANOVA at p=.05
** weighted by percent coverage per species from Table 1

## Elevation effects

The June biomass data revealed an overall trend of higher biomass with higher elevation for the three main species (Table 3). A high degree of variability with the low sample number (3/elevation/species) has probably precluded this trend from being statistically significant at the 95% level of confidence, indicating the need for considering increased sampling in future monitoring if justified by the objectives. However this pattern is consistent with the previous year's biomass sampling results (AIM and CARR, 2000). Lenticulate sedge showed, as in the 1999 data, a tendency toward declining biomass after peaking at elevation 436 m. This may reflect increasing competition from reed canarygrass which dominated the vegetation cover in the higher elevation bands.

**Table 3: Standing biomass (g/m2 AFDW) for area P by species and elevation (June data)**

| Elevation | Reed canarygrass ($g/m^2$) | **Lenticulate sedge** ($g/m^2$) | Columbia sedge ($g/m^2$) |
|---|---|---|---|
| **434 m** | 240.1 | 1502.7 | n/a |
| **435 m** | 262.5 | 1961.5 | n/a |
| **436 m** | 148.4 | 2322.9 | 380.3 |
| **437+ m** | 470.4 | 2167.6 | 527.6 |

### Effect of inundation

For the post-inundation assessment in October, the standing biomass was separated into standing live (green) and standing dead (brown) fractions to help understand the impact of three months of inundation on each species. Leaves that were partially dead (i.e. brown tipped) were considered live, while only leaves that were predominantly brown classified as dead. No attempt was made to subdivide individual leaves into live or dead portions. Only reed canarygrass, lenticulate sedge and Columbia sedge were included in the sampling. At 435m - 437+ m, which was the elevation range exposed by that date, there were insufficient pure stands of horsetail available for sampling.

By October, the average live standing biomass (including all species) was approximately half of the June standing crop (Table 4).

**Table 4: Biomass (g/m2 AFDW) for area P by species after inundation (October data)**

| | Reed canarygrass | Lenticulate sedge | Columbia sedge |
|---|---|---|---|
| Standing Live ($g/m^2$ AFDW) | 127.0 | 540.9 | 235.0 |
| Standing Dead ($g/m^2$ AFDW) | 102.9 | 1054.2 | 151.3 |
| Total ($g/m^2$ AFDW) | 229.9 a* | 1595.2 b | 386.3 a |
| % Die back | 44.8% | 66.1% | 39.2% |

within row, values with different letters are statistically different using ANOVA at p=.05

On average over the entire elevation range, the lenticulate sedge demonstrated the greatest level of die-back, retaining approximately one-third of its pre-inundation biomass as live material. The reed canarygrass retained slightly more than half of its June biomass as live material. Columbia sedge appeared to be the most tolerant of inundation, retaining over 60% of its biomass as live material. However this may be misleading as Columbia sedge only appears in the higher elevation bands which were subject to less total inundation than the other species that are present over the entire elevation range.

Inundation also had a further impact on the aboveground biomass through a significant loss from the site of shoot material between the pre- and post-inundation assessments (Table 5). Depending on water elevations, the higher elevations may be more susceptible to physical breakage by surface wind and wave action, this pattern of increased loss of biomass with increasing elevation is not unexpected.

**Table 5: Percent change in above ground biomass due to inundation and elevation**

| Elevation | Reed canarygrass | Lenticulate sedge | Columbia sedge |
|---|---|---|---|
| **435 m** | -25% | -22% | n/a |
| **436 m** | -28% | -21% | -5% |
| **437+ m** | -46% | -35% | -22% |

### Plant nutrients

Concurrent with the species specific sampling for standing biomass, aboveground biomass and root samples were collected for nutrient tissue analysis. In 2000, pre- and post-inundation nutrient content of nitrogen (N), phosphorus (P) and potassium (K) were determined for all vegetation components of lenticulate sedge, Columbia sedge and reed canarygrass. The nutrient data for each species are presented in Tables 6 to 8 for N, P and K, respectively.

Although there was a strong elevation trend with biomass production for each of the species, this pattern was not as consistent for nutrient content, indicating very different growth responses to the annual operating regime. The pre-inundation (June 2000) pattern for increasing shoot nutrient content for reed canarygrass with increasing reservoir elevation (i.e. longer growing season and higher biomass) as seen in Table 6 for %N was also evident for %P (Table 7) and %K (Table 8). However lenticulate sedge exhibited the same strong trend only in %N, and to a lesser degree with %P. Columbia sedge, with a more limited elevation range (436m and 437+m), did not exhibit any shoot nutrient content pattern.

**Table 6: Summary of N% in shoots and roots according to elevation and species**

| Species | Elev. | June 2000 | | October 2000 | | |
|---|---|---|---|---|---|---|
| | | *Shoot* | *Root* | *Live Shoot* | *Dead Shoot* | *Root* |
| *Reed Canarygrass* | 434 m | 0.78% a** | 0.68% a | na* | na | na |
| | 435 m | 0.99% b | 0.64% a | 1.04% a | 0.60% a | 0.84% a |
| | 436 m | 2.01% c | 0.64% a | 2.13% c | 0.77% a | 0.84% a |
| | 437+m | 1.63% c | 0.88% a | 1.61% b | 0.73% a | 1.19% a |
| Lenticulate sedge | 434 m | 1.22% a | 0.78% a | na* | na | na |
| | 435 m | 1.35% b | 0.52% a | 1.28% ab | 0.60% a | 1.16% a |
| | 436 m | 1.63% c | 0.65% a | 1.16% a | 0.73% a | 1.12% a |
| | 437+m | 1.73% c | 0.88% a | 1.40% b | 0.82% a | 1.45% a |
| Columbia sedge | 436 m | 2.41% a | 0.68% a | 1.86% a | 0.69% a | 1.54% a |
| | 437+m | 2.23% a | 0.61% a | 1.52% a | 0.69% a | 1.46% a |

* not available, 434 m was submerged at the time of sampling
** within row, values with different letters are statistically different at 95% level of confidence

Differences in species growth response to inundation became further evident with the data from the post-inundation (October 2000) sampling. Although the dead shoot nutrient content of each species was lower for all three nutrients than the live shoots, as would be expected, the response of the residual live shoots and root to inundation was quite varied. For reed canarygrass, neither the %N nor %P content of the live shoots demonstrated a decrease due to inundation and seasonal change, and the associated decrease in the dead shoots was accompanied with an increase in root content. It appears that reed canarygrass is a very tight internal nutrient cycler of nitrogen and phosphorus. The same pattern was also evident in %P for the two other species. Although both lenticulate sedge and Columbia sedge exhibited a decrease in live shoot %N, with the accompanying increase in root nutrient content, it appears they are also relatively tight internal nutrient cyclers of N.

**Table 7: Summary of P% in shoots and roots according to elevation and species**

| Species | Elev. | June 2000 | | October 2000 | | |
|---|---|---|---|---|---|---|
| | | *Shoot* | *Root* | *Live Shoot* | *Dead Shoot* | *Root* |
| Reed Canarygrass | 434 m | 0.11% a** | 0.11% a | na* | na | na |
| | 435 m | 0.15% a | 0.08% a | 0.13% a | 0.08% a | 0.11% a |
| | 436 m | 0.15% a | 0.06% a | 0.31% b | 0.19% b | 0.12% a |
| | 437+m | 0.26% b | 0.11% a | 0.23% ab | 0.11% a | 0.10% a |
| Lenticulate sedge | 434 m | 0.17% a | 0.15% a | na* | na | na |
| | 435 m | 0.19% a | 0.09% a | 0.15% a | 0.10% a | 0.10% a |
| | 436 m | 0.15% a | 0.07% a | 0.17% a | 0.12% a | 0.12% a |
| | 437+m | 0.24% b | 0.11% a | 0.23% a | 0.15% a | 0.18% a |
| Columbia sedge | 436 m | 0.28% a | 0.12% a | 0.23% a | 0.15% a | 0.15% a |
| | 437+m | 0.29% a | 0.12% a | 0.21% a | 0.17% a | 0.23% a |

* not available, 434 m was submerged at the time of sampling
** within row, values with different letters are statistically different at 95% level of confidence

**Table 8: Summary of K% in shoots and roots according to elevation and species**

| Species | Elev. | June 2000 | | October 2000 | | |
|---|---|---|---|---|---|---|
| | | *Shoot* | *Root* | *Live Shoot* | *Dead Shoot* | *Root* |
| Reed Canarygrass | 434 m | 1.36% a** | 0.83% a | na* | na | na |
| | 435 m | 1.77% ab | 0.50% a | 0.92% a | 0.50% a | 0.43% a |
| | 436 m | 2.18% b | 0.57% a | 1.61% b | 0.80% b | 0.68% a |
| | 437+m | 2.07% b | 0.54% a | 1.51% b | 0.50% a | 0.43% a |
| Lenticulate sedge | 434 m | 2.16% a | 0.67% a | na* | na | na |
| | 435 m | 2.22% a | 0.73% a | 1.22% a | 0.80% a | 0.49% a |
| | 436 m | 2.20% a | 0.59% a | 1.07% a | 0.70% a | 0.68% a |
| | 437+m | 2.19% a | 0.54% a | 1.06% a | 0.60% a | 0.65% a |
| Columbia sedge | 436 m | 2.31% a | 0.61% a | 1.58% a | 0.60% a | 0.61% a |
| | 437+m | 2.34% a | 0.77% a | 1.45% a | 0.77% a | 0.77% a |

* not available, 434 m was submerged at the time of sampling
** within row, values with different letters are statistically different at 95% level of confidence

However, all three species appeared to be less frugal with potassium. In addition to the expected decrease in %K with the dead shoots, there was also a decrease in %K content with the residual standing live shoots and no associated increase in root %K content. This indicates that unlike the tightly cycled nitrogen and phosphorus, potassium in these plants is readily leached from the shoots during inundation and readily available to the aquatic environment.

### 3.1.3 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).

#### Soil carbon

The total soil carbon analysis on the soil from area P demonstrated a significant effect of species and elevation (Table 9). This was expected, since it is the quantity of organic inputs (shoot and root detritus) and their subsequent incorporation into the soil matrix that changes the soil carbon content over time.

**Table 9: Total soil carbon (%) by elevation and depth for each species**

| Depth | Area - Elevation | | | | | |
|---|---|---|---|---|---|---|
| | P-434 m | P-435 m | P-436 m | P-437+ m | G-436+ m | Control ** |
| **Reed Canarygrass** | | | | | | |
| **0-10 cm** | 0.93% a* | 0.81% a | 1.96% a | 3.27% a | 1.73% a | 0.19 % a |
| **10-20 cm** | 0.94% a | 1.22% a | 1.15% b | 1.34% b | 0.87% b | 0.18% a |
| **20-30 cm** | 0.27% b | 0.99% a | 0.73% c | 0.89% c | n/a | 0.18% a |
| **Lenticulate sedge** | | | | | | |
| **0-10 cm** | 2.27% a* | 1.91% a | 2.17% a | 3.22% a | 1.87% a | 0.19 % a |
| **10-20 cm** | 1.04% b | 1.09% b | 1.22% b | 1.52% b | 0.99% B | 0.18% a |
| **20-30 cm** | 0.87% b | 0.49% c | 0.43% c | 1.13% c | n/a | 0.18% a |
| **Columbia sedge** | | | | | | |
| **0-10 cm** | *** | *** | 1.12 a | 1.20 a | *** | 0.19 % a |
| **10-20 cm** | *** | *** | 0.94 a | 0.80 b | *** | 0.18% a |
| **20-30 cm** | *** | *** | 0.47 b | 0.41 c | *** | 0.18% a |

* within columns for each species, values with different letters are statistically different by depth at 95% level of confidence
** Control samples are from a surrogate control area at Blanket Creek
*** Species not present for sampling

The elevation influence on reed canarygrass production is most evident in the surface horizon carbon concentration, with soil carbon concentration in the surface horizon (0-10 cm) increasing from approximately 1% at 434 m and 435 m to approximately 2% at 436 m, and over 3% at 437+ m. The elevation effect on the sedges is not as dramatic.

The data also demonstrate the significant effect of soil depth on carbon accumulation, with most of the carbon in the upper 10 cm, the area with the highest root biomass. There is a rapid decrease in carbon concentration in the lower two layers. When compared to the soil carbon level from the surrogate control area, ~0.20%C throughout the soil depth of interest, it also appears that the accumulation of soil carbon appears to continue past 30 cm.

## Carbon pool – biomass plus soil

In Table 10, an estimate of the average total carbon pool (tC/ha) for area P and G has been developed using the species composition data from the field survey and averages for each species within the respective areas. This carbon estimate for each species includes aboveground biomass C, below ground (root) biomass C and total soil C (0-30 cm depth). The total carbon pool for each area is based on the percent coverage of each species (i.e. weighted as a percent of the overall coverage).

**Table 10: Average total carbon pool (tC/ha), weighted by plant cover composition and species specific carbon totals over the available elevation range.**

| . | Area P | | Area G | |
|---|---|---|---|---|
| **Species** | % cover | Weighted C contribution | % cover | Weighted C contribution |
| Reed canarygrass | 65% | 25.5 | 86% | 36.4 |
| Lenticulate sedge | 27.5% | 16.1 | 11% | 5.0 |
| Columbia sedge | 0.5% | <0.1 | 0 | 0 |
| Bare soil | 8% | 0.5 | 3% | 0.2 |
| **Weighted TOTAL** | | **42.1 tC/ha** | | **41.6 tC/ha** |
| vs. Control (bare soil)* | 100% | 5.7 tC/ha | 100% | 5.7 tC/ha |

* bare soil is the unvegetated sandy material from Blanket Creek

On a per hectare basis, there is no significant difference for the carbon production between the two sites, although there are differences in elevation distribution and cover composition. Elevation trends may be expected with refinement of this calculation by elevation, a possibility in future studies integrating the new orthophotos and DTM with more elevation specific GPI vegetation surveys. The important interpretation from this data is the level of carbon accumulation achieved by the revegetation of what was previously a problem source drawdown zone.

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.

## *3.2 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). 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 vigor) 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.

### 3.2.1 Vegetation change over time

Overall, in 2000, perennial vegetation occupied **498.7 ha** in areas F through T (Table 11). This represents a large decline from the pre-impoundment area of **1,046.1 ha**.

**Table 11: 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.

### 3.2.2 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 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 12). Between 434 m and 440 m, each of the plant communities exhibits a different development pattern as a function of elevation, reflecting it tolerance to inundation and vegetation competition.

**Table 12: 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.

### 3.2.3 Extrapolation of aboveground biomass estimates to study area

Determination of vegetation biomass by area (F through T) using airphoto interpretation and mapping was undertaken for the entire study area as part of this synthesis report, much of which was not sampled during the field studies due to access limitations. The large scale (1:5,000), high-resolution color airphotos allowed for a subjective density rating scheme to be applied to the observed vegetation types. During the airphoto interpretation and mapping exercise, the density of perennial vegetation was inferred from the distribution of vegetation patches, textural patterns, height of vegetation and amount of bare ground visible between plant stems. The vegetation mapping was followed by GIS analyses that resulted in tabulated data for vegetation types, densities and areas. Due to the detail included in the original mapping, the vegetation types were consolidated according to their dominant vegetation, i.e. horsetail, reed canarygrass, and sedge. A growth performance rating was then determined for each major vegetation group based on the airphoto interpretation. The ratings were as follows:

- I - incipient (sparse cover, much bare ground evident)
- L – low density, short, patchy or sparse growth
- M – moderate density, relatively open canopy, and/or shorter plants than for H
- H – high density, lush vigorous growth

Field verification of species composition and plant densities for the mapping project was undertaken in June 2001. This allowed for subsequent refinement of the mapping based on field inspection and correlation of the growth performance classification with data collected the previous two years.

After a comparison of the field-derived biomass values and the mapping-derived growth performance ratings, a characteristic aboveground biomass value (also referred to as the Biomass Multiplier) was determined for each major plant community and growth performance category. These results were interpreted bearing in mind that slight differences in topography and substrates can significantly affect the distribution of species, density and biomass. Similarly, year to year variability can be expected in species growth response to inundation and climate factors. Seasonal changes in biomass and growth rates, as documented in the biomass sampling program in 2000 (CARR and AIM, 2002), must also be considered in the use of a characteristic biomass multiplier.

Recognizing the above factors, values used to characterize each growth performance class for this study were developed based on the assumption that the vegetation will be inundated by the end of June, as would be usual for most years. If the vegetated areas are not inundated (as was the case in 2001), growth would be expected to be much higher, peaking in August. In such years, the overall biomass production could be significantly greater than that calculated for the average year. The estimate of aboveground biomass for the entire dust control area is presented in Table 13.

The aboveground biomass results can further be used to estimate the nutrient pool available for ecosystem use during the terrestrial and/or aquatic phases of the study area. Characteristic nutrient values are provided for %N, %P and %K for each of the plant communities and growth performance ratings based on the 2000 field study (CARR and AIM, 2002) to yield an estimate of available nutrient pool (Table 14).

**Table 13: Aboveground biomass estimated for permanent vegetation community for all dust control areas (F through S)**

| Plant Community | Growth Performance Rating | Total Area | Biomass Multiplier | Total Estimated Biomass |
|---|---|---|---|---|
| **Horsetail** | I | 2.28 ha | 25 $g.m^{-2}$ | 0.6 t |
| | L | 9.59 ha | 50 $g.m^{-2}$ | 4.8 t |
| | M | 15.34 ha | 75 $g.m^{-2}$ | 11.5 t |
| | H | 3.05 ha | 100 $g.m^{-2}$ | 3.0 t |
| | **Strata Total** | **30.26 ha** | | **19.9 t** |
| | | | | |
| **Reed Canarygrass** | I | 50.83 ha | 100 $g.m^{-2}$ | 50.8 t |
| | L | 63.97 ha | 250 $g.m^{-2}$ | 159.9 t |
| | M | 126.40 ha | 400 $g.m^{-2}$ | 505.6 t |
| | H | 120.14 ha | 550 $g.m^{-2}$ | 660.7 t |
| | **Strata Total** | **361.34 ha** | | **1377.1 t** |
| | | | | |
| **Sedges** | I | 36.65 ha | 100 $g.m^{-2}$ | 36.6 t |
| | L | 27.03 ha | 250 $g.m^{-2}$ | 67.6 t |
| | M | 27.74 ha | 400 $g.m^{-2}$ | 111.0 t |
| | H | 0.42 ha | 550 $g.m^{-2}$ | 2.3 t |
| | **Strata Total** | **91.84 ha** | | **217.5 t** |
| | | | | |
| **TOTALS** | | **483.44 ha** | | **1614.5 t** |

As with the biomass multiplier used in Table 14, there can be considerable variability in nutrient levels from year to year, within the growing season, and along elevation gradients. The results of this exercise should be used cautiously due to these limitations.

**Table 14: Aboveground nutrients (N, P and K) estimated for permanent vegetation community for all dust control areas (F through S)**

| Plant Community | Growth Performance Rating | Total Estimated Biomass | Characteristic Nutrient Level | | | Estimated Total Nutrients (kg) | | |
|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | N | P | K |
| **Horsetail** | I | 0.6 t | 1.6% | 0.17% | 2.6% | 10 | 1 | 15 |
| | L | 4.8 t | 1.6% | 0.17% | 2.6% | 77 | 8 | 124 |
| | M | 11.5 t | 1.9% | 0.17% | 2.7% | 219 | 20 | 310 |
| | H | 3.0 t | 1.9% | 0.17% | 2.7% | 57 | 5 | 81 |
| | **Strata Total** | **19.9 t** | | | | **363** | **34** | **530** |
| | | | | | | | | |
| **Reed Canarygrass** | I | 50.8 t | 0.8% | 0.10% | 1.4% | 406 | 51 | 711 |
| | L | 159.9 t | 1.0% | 0.15% | 1.8% | 1,599 | 240 | 2,878 |
| | M | 505.6 t | 1.6% | 0.15% | 2.2% | 8,090 | 758 | 11,123 |
| | H | 660.7 t | 2.0% | 0.25% | 2.2% | 13,214 | 1652 | 14,535 |
| | **Strata Total** | **1377.1 t** | | | | **33,404** | **2701** | **29,065** |
| | | | | | | | | |
| **Sedges** | I | 36.6 t | 1.2% | 0.15% | 2.2% | 439 | 55 | 805 |
| | L | 67.6 t | 1.4% | 0.20% | 2.2% | 946 | 135 | 1,487 |
| | M | 111.0 t | 1.7% | 0.20% | 2.2% | 1,887 | 222 | 2,442 |
| | H | 2.3 t | 1.7% | 0.25% | 2.2% | 39 | 6 | 51 |
| | **Strata Total** | **217.5 t** | | | | **3,311** | **418** | **4,785** |
| | | | | | | | | |
| **TOTALS** | | **1614.5 t** | | | | **37,078** | **3,153** | **34,380** |

## 4.0 SUMMARY AND RECOMMENDATIONS

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.

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Table of Contents