Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Monitoring Program Terms of Reference

- **CLBMON-35 Plant Response to Timing and Duration of Inundation**

Revision 1
January 7, 2016

CLBMON-35 – Plant Response to Timing and Duration of Inundation Monitoring Program Terms of Reference Revision 1

1 Study Rationale

1.1 Purpose for Revision

The original intent for CLBMON-35 Terms of Reference[1] was to determine, via planting trials in a greenhouse setting and in prescribed areas in the Arrow Lakes Reservoir (ALR), how inundation and other factors would affect plant survival in the ALR. The results of these trials then would be used, in conjunction with ALR-based studies, to determine whether the vegetation objectives, as set out by the Columbia Water Use Plan (WUP) (BC Hydro 2007) Consultative Committee (CC), are being met through ALR operations. However, the implementation of this study was postponed due to resource constraints.

In 2014, BC Hydro conducted a technical review of its Revegetation Programs and associated monitoring studies within the ALR and the Kinbasket Reservoir (KIN). A number of recommendations came out of the Revegetation Technical Review (RTR), including the need to catalogue and analyze data collected to date. The catalogue would include data from the CLBWORKS programs within the ALR and KIN, including vegetation treatment and control sites. The purpose of the catalogue exercise would be to ascertain what variables (biotic and abiotic) contributed to the successes or failures of each type of vegetation treatment at a given site. The goal of cataloguing and analyzing these data is to help elucidate the extent to which 'reservoir filters' impact plant species survival within the drawdown zone. Filters or constraints are variables which prevent vegetation from becoming established (e.g., presence of woody debris, erosion and deposition, wave and wind action, substrate compaction, human activity, soil anoxia). In addition, CLBMON program results, which analyze existing vegetation in the drawdown zone, will be summarized and compared to CLBWORKS to further ascertain which variables in the drawdown zone promote the survival of plant species and plant communities. Ultimately, this information may be used to tease-out the impacts of ALR and KIN operating regimes, and to develop improved remediation prescriptions for self-sustaining vegetation communities in the future. Participants at the RTR agreed with this approach.

Management questions in the original CLBMON-35 TOR align with this catalogue recommendation, and the purpose of this TOR revision is to outline how the catalogue data will be used to analyze species response to inundation, instead of completing resource intensive field and greenhouse trials, as outlined in the original TOR. Although the original CLBMON-35 TOR was focused on the ALR, given the challenges of the revegetation program in KIN, this TOR has been expanded to include KIN data in the analyses as well.

As the ALR and KIN are separate watersheds within different biogeoclimatic zones (i.e., they have different vegetation communities), as well as having different operating regimes, two catalogues will be developed: one for ALR and one for KIN. Furthermore, each catalogue will involve three components: i) compilation of data

[1] The Terms of Reference dated April 8, 2008 and amended March 26, 2009.

and analysis of data from physical works (CLBWORKS-1 and 2) ii) a results summary of the survival of planted vegetation species (from CLBMON-9 and 12), and iii) a results summary of the existing vegetation species and communities establishing and growing naturally in the drawdown zones (from CLBMON-12 and 33). Management Questions associated with the catalogue are provided below. The catalogues should be compatible with each other.

1.2 Background

At the time of the Columbia WUP (BC Hydro 2007) process, limited information was available on the absolute limits of plant endurance or which aspects of the reservoir operating regime (i.e. inundation timing, frequency, depth or duration) were the most significant for plant survival. This lack of specific information hindered the WUP CC's ability to assess the performance of operating alternatives for ALR and KIN on existing vegetation communities. Numerous assumptions were built into the vegetation performance measures, which the WUP CC acknowledged, needed to be tested to improve future decision making regarding reservoir management. A key assumption used in deriving the vegetation performance measure scores was that plant condition and survival is constrained by the opportunity for spring growth. Soft constraint targets for the ALR operating regime were identified in the Columbia WUP. The targets for the soft constraints were to create an optimal reservoir operation for vegetation that would maximize plant growth within ALR. Soft constraints were not identified for KIN.

In 2007, the Columbia WUP CC recommended a monitoring program comprised of a series of interlinked studies at different spatial scales to investigate the effects of operating regimes on vegetation communities. In an effort to seek input from First Nations on the design of monitoring and physical works programs, BC Hydro met with members of the Ktunaxa Nation's Cultural Knowledge and Language committee on September 28, 2007. Following a presentation from BC Hydro about the reasons for undertaking the revegetation programs, as well as the challenges and opportunities involved, Ktunaxa elders were asked if they would be interested in a subsequent meeting with BC Hydro to discuss their cultural knowledge of plants. The subsequent meeting took place at St. Eugene's Mission Resort on November 23, 2007. As a part of this investigation, BC Hydro consulted with Ktunaxa to create a list of cultural plants, their uses and their occurrence in the drawdown zones of both the KIN and ALR. Two traditional plant lists were created and species tolerant of inundation were used in the application of the physical works programs.

Since the inception of the Columbia WUP a number of monitoring and works programs have been implemented in the ALR and KIN:

- **CLBWORKS-1** Kinbasket Reservoir Revegetation Program: a reservoir-wide revegetation program to enhance sustainable vegetation growth within the drawdown zone of Kinbasket Reservoir to benefit fish, wildlife, aesthetics, dust control and recreation.
- **CLBWORKS-2** Mid-Columbia River and Arrow Lakes Reservoir Revegetation Program: a 5-year revegetation program to enhance sustainable vegetation growth within the drawdown zone of the mid-Columbia River and the Arrow Lakes Reservoir to benefit fish, wildlife, aesthetics, dust control and recreation.

- **CLBMON-9** Kinbasket Reservoir Monitoring of Revegetation Efforts: a 10-year program to evaluate plant survival and monitor representative planting sites under the various revegetation treatments in Kinbasket Reservoir.
- **CLBMON-10** Kinbasket Reservoir Inventory of Vegetation Resources: a 10-year program to assess and map vegetation distribution by elevation and identify riparian wildlife habitat within Kinbasket Reservoir.
- **CLBMON-12** Mid-Columbia River and Arrow Lakes Reservoir Monitoring of Revegetation Efforts: a 10-year program to evaluate plant survival and monitor representative planting sites under the various revegetation treatments in the mid-Columbia River and Arrow Lakes Reservoir.
- **CLBMON-33** Arrow Lakes Reservoir Inventory of Vegetation Resources: a 10-year program to assess and map vegetation distribution by elevation and identify riparian wildlife habitat in relation to inundation cycles and revegetation efforts in the mid-Columbia River and Arrow Lakes Reservoir.

Currently these programs are in various stages of completion. However, many of the monitoring programs have recommended additional studies be completed on the influence of timing, duration and inundation, and the number of available growing degree days on vegetation establishment and survival.

CLBMON-10 has been monitoring vegetation communities in the KIN between the elevations of 741 and 754 m for six years (in 2015a). The influence of reservoir operations since 2007 has resulted in notable reductions to the structure and composition of vegetation communities in species richness diversity for communities occurring at the highest elevations of the drawdown zone (i.e., ≥750m, Hawkes et al 2015a). In addition, the timing and duration of inundation influence the number of growing degree days (GDDs) available to vegetation in different zones of the reservoir (Hawkes et al 2015a) which influences vegetation survival. The program has concluded that it is difficult, without direct experimentation, to separate out the relative importance of wet stress and GDD's in modulating patterns of plant distribution and abundance on the landscape. GDD's may prove to be an important factor that ultimately limits the capability of certain vegetation communities to expand in spatial extent, or of new communities to become established (Hawkes et al 2015a).

CLBMON-9 has completed four years of study (in 2013) to assess the effectiveness of revegetation treatments applied (CLBWORKS-1) in the drawdown zone of KIN. Since 2008, approximately 69 ha of the drawdown zone have been treated. No statistically significant differences have been detected between treatment and control plots either in percent cover of vegetation, species richness, or species diversity within any plant community, elevation band, or region of the reservoir (Hawkes et al 2013a). The quality or quantity of native vegetation in the KIN has not increased as a result of the CLBWORKS-1 planting program (Hawkes et al 2013). It is apparent from the 2013 assessment that without some level of adaptive management, the program will likely continue to struggle and any successes in establishing vegetation in the drawdown zone will be relatively minor (Hawkes et al 2013).

The CLBMON-33 program implements in alternate years and has completed five years of study (in 2014), and has been monitoring the impacts of the soft constraints operating regime (BC Hydro 2007) on existing vegetation in ALR since 2007. The

primary objective is to monitor landscape level changes in the spatial extent, structure, and composition of vegetation communities within the 434-440 m ASL elevation band of the drawdown zone, and to assess if any observed changes are attributable to the soft constraints operating regime. Based on results from 2014, no statistically significant differences were found in vegetation community type (VCT) frequencies or polygon composition between 2007 and 2014 within the drawdown zone (Miller et al 2015b). The ALR drawdown zone is a moderately dynamic system at the local scale but relatively stable at the landscape level. Changes may take long periods of time to become apparent; there is currently no compelling evidence that the soft constraints operating regime is failing to maintain vegetation spatial limits, structure, and composition of existing vegetation communities in the drawdown zone (Miller et al 2015b). However, recommendations include the analysis of GDD's as a potential management tool for fine-tuning soft constraints operating regimes to maximize desired vegetation values in the Arrow Lakes drawdown zone (Miller et al 2015b).

CLBMON-12 is currently in the fourth year of study (field sampling every odd year since 2009), to investigate site-level changes in vegetation in response to various direct and indirect influences, including revegetation treatments; climate; topography; and parent materials. Data from CLBMON-33 is used to provide continuity from year to year with CLBMON-12. A specific goal of this study has been to assess the effectiveness of the CLBWORKS-2 ALR Revegetation program, which began in 2008, and finished in 2011.

CLBMON-12 results to date indicate that low-elevation vegetation communities are somewhat negatively influenced by prolonged inundation in the midsummer to fall period (Enns et al 2013). Some of the low-elevation vegetation has been reduced in cover or height. However, many of the plant species in the drought-tolerant vegetation community types at higher elevation benefit from brief inundation if they are not impacted by wave scour. Based on a comparison with 2009, there was a slight increase in vegetation cover, height, richness and diversity, and distribution became more even in both revegetated and control plots between 2009 and 2013 (Enns et al 2013). The number of days of inundation and the depth of inundation (which affect GDD's), and the relative proportion of sand, silt and gravel in the substrate accounted for most of the variation in plant cover. Duration of inundation exceeding 100 days negatively influenced plant height in both treated and control plots (Enns et al 2013).

1.3 Management Questions

Under this revised Terms of Reference for CLBMON-35, data to date from the CLBWORKS programs revegetation treatments and results from the four vegetation monitoring programs (CLBMON-9, 10, 12, and 33) will be assimilated into two catalogue-style databases (one for each reservoir ALR and KIN) which will developed to answer these management questions. Analysis already completed for the monitoring programs should not be replicated in this study. Management questions will be answered separately for each reservoir; these questions also assume the data is sufficient and available to answer these questions:

1. What trends are apparent in the responses of plant species used for revegetation to the operating regimes to date with respect to timing, frequency, duration and depth of inundation?

2. Do plant species respond differently from one another to variables of the operating regime, including timing, frequency, duration and depth of inundation?
3. How do the responses of plant species to the operating regime interact with other biotic and abiotic factors (e.g., substrate, climate, reservoir filters, presence of other plant species)?
4. What recommendations may be made to more effectively maintain existing vegetation, help persisting species, and establish new plant communities at different spatial scales (i.e. community vs. species scale) in the future?

The intent of this study is to summarize conclusions from the four monitoring studies and expand the analysis and conclusions by incorporating data from the physical works studies. Hopefully this study will be able to answer why the physical works programs failed or succeeded, and why other existing plant communities or species are successful in persisting in reservoir drawdown zones. Answering these management questions will help resolve key uncertainties regarding the influence of operating conditions of ALR and KIN on vegetation.

1.4 Management Hypotheses

The creation of management hypotheses and sub-hypotheses should be derived with respect to the limitations of the data collected; the analysis completed to date; and provide the most complete answers to the management questions. Proposed hypotheses will be reviewed by BC Hydro prior to implementation.

1.5 Key Water Use Decision Affected

This study will provide information regarding impacts to existing vegetation, and revegetation physical works from the current operating regimes for ALR and KIN. The decision of the WUP CC to implement revegetation programs in lieu of operational changes in the reservoirs was based on the assumption that these programs could be successful under the current operations. The soft constraints for maintaining (or enhancing) existing vegetation communities and associated ecosystems in the drawdown zone through maintaining lower water levels during the growing season were proposed for the ALR (BC Hydro 2007). However, the 5-year interim review (BC Hydro 2014) found that it has not been possible for BC Hydro to implement the vegetation soft constraint for the ALR for the first six years of the WUP due to: a) obligations under the Columbia River Treaty, which limit the operational flexibility of the reservoir, b) uncertainty in weather and inflow forecasts in the Columbia basin, and c) the inherent conflict between soft constraints.

Findings from this study may help to inform future operating decisions regarding impacts on plant species survival at different elevations in the drawdown zones of each reservoir, as well as planting methods and locations for any future revegetation efforts.

2 Study Proposal

2.1 Objective and Scope

The scope of the reservoir catalogue exercise is to ascertain what variables (biotic and abiotic) contributed to the successes or failures of each type of vegetation

treatment implemented during the physical works programs at a given site. Monitoring program results will be summarized and compared to the physical works data to further ascertain which biotic and abiotic variables in the drawdown zone promote the survival of existing plant species and existing plant communities to help understand why some species and plant communities are persisting in the drawdown zones of each reservoir. The compilation of existing results from the monitoring programs and analysis of the physical works data to answer the management questions should provide information to evaluate the long-term effects of the operations and to develop *a priori* predictions about the potential effects of future alterations of operations to plant species distributions in the drawdown zone. This study is not intending to repeat analysis completed as part of the monitoring programs (CLBMON-9, 10, 12 and 33), but draw inferences between the programs and determine reservoirs conditions which culture plant species and plant community survival. Gaps in the data may be identified during compilation of the data into the two reservoir catalogues.

The objectives of this study are to:

- Summarize results from the monitoring programs and collate and analyze data collected under the physical works studies. If gaps are identified, recommend additional data collection as part of the monitoring studies.
- Using those results and data, along with any new information required to be collected to fill data gaps, link the effects of reservoir operations to larger-scale trends in vegetation composition, structure, species response and spatial extent for each ALR and KIN.
- Answer why the physical works programs failed or succeeded, and why other existing plant communities or species are successful in persisting in reservoir drawdown zones by identifying biotic or abiotic site conditions which foster or hinder growth.
- Recommend strategies for future revegetation program efforts and operations based on the results of this study.

The rationale for this study is to see what we can learn before the end of the WUP, avoid repeating studies, and make sure we are collecting the appropriate data that is needed to best answer the management questions. Identifying gaps in the data now will allow additional data collected in the field as part of the existing monitoring programs during the current WUP period. Further secondary analysis will be necessary closer to the end of the monitoring programs in order to incorporate additional collected data in 2019.

2.2 Approach

Two catalogues will be developed for this study: one for ALR and one for KIN. Each catalogue will compile: i) data from the physical works studies, ii) summary of the results from the analysis of the survival of planted vegetation species (treated sites), and iii) a results summary of the existing vegetation species and communities establishing and growing naturally in the drawdown zones The Management Questions listed above will be answered for the ALR and the KIN. Results from the existing programs will be summarized and not repeated.

This study may require a statistical analysis using existing data collected to date. Summarizing results from existing data sets and additional new analysis is expected to address uncertainties regarding the relative contribution of variations in the operating regimes, elevation location in the drawdown zone, environmental conditions, and multi-year stressors on species survival. To answer the management questions, it is expected that representative plant species be selected for analysis. Cultural use plants will be considered in this analysis. Relationship trends will be analyzed between plant species survival, environmental variables, and spatial patterns. Gaps in the data should also be identified and addressed through recommendations for additional data collection in the field within the remaining monitoring periods for CLBMON-9, 10, 12 and 33.

2.3 Methods

Task 1: Project Coordination

Project coordination will involve the general administrative and technical oversight of the program, which will include, but not be limited to: 1) budget management, 2) start-up meeting with BC Hydro 3) raw data compilation, including GIS, and database creation, 4) data gap analysis 5) statistical design meeting with BC Hydro 5) statistical analysis including a review of existing data and associated analyses and findings, 6) QA/QC of results,7) reporting and 8) presenting at a stakeholder meeting.

Participation in planning processes for other programs under the ALR and KIN Revegetation Management Plan, maintenance of data records, and facilitation of data transfer among other investigations associated with the KIN and ALR Revegetation Management Plan may also be required.

Task 2: Data Review and Compilation

Gather all available data (including GIS data and ortho photos) collected for the identified monitoring and works programs between 2007 and present. Compile and organize the data in a way that will be compatible with BC Hydro's database systems (Access), and which will enable statistical analysis of the appropriate variables required for this program to complete a data gap analysis, a results summary, and to observe spatial trends in the data.

Task 3: Data Gap Analysis and Field Collection

To be able to answer the management questions: complete a data gap analysis with the compiled data, focusing on filling gaps from the CLBWORKS and possibly the CLBMON programs. Recommend additional data collection as part of the existing CLBMON programs to fill gaps which will be required to observe spatial trends in the data (i.e. the effects of soil anoxia on plant persistence within the drawdown zone).

Task 4: Data Collation Design and Analysis

Design

A detailed description and summary of completed data analysis and new analysis, including limitations and benefits of the selected method(s) and a discussion of statistical power/sample size for each catalogue, will be provided.

Due to the complexity of the physical habitats of the reservoir drawdown zone, the involvement of a biostatistician will likely be required to ensure that data analysis utilize statistically valid approaches for testing the management hypotheses and drawing causal inferences to support the management questions. The design will necessitate a good understanding of the analyses which have been completed to date, and not repeat any analysis which has been completed to date.

It is expected that use of classical statistical methods will be limited due to the variability of the existing data sets which will be different for each reservoir; therefore, multivariate/spatial/ordination techniques will likely need to be utilized

Analysis

Analysis will use data from a range of elevations and vegetation community types (VCT's); species analysis should include a series of decreasing elevations in the reservoir drawdown zone from 440 m-434 m in the ALR, and 754-741 m in the KIN. Randomization and replication of plot selection in the data analysis at each elevation zone (stratum) will be required (where possible).

Planted Vegetation: Analysis (CLBWORKS programs)

Where able, relationship trends will be analyzed between planted vegetation survival and mortality, and environmental variables and "reservoir filters". For example:

- Planting methods (including time of year and size of plant if available);
- Climate;
- Substrate;
- Soil;
- Invasive species and competition with local biota;
- Aspect, slope, drainage;
- Elevation;
- Woody debris (Kinbasket);
- Erosion and deposition
- Wind and wave influence;
- Recreation disturbance;
- Competition of planted vegetation with existing or establishing species; and
- The positive or negative impacts of planted vegetation on local biota.

Existing Vegetation: Results Programs Summary and New Analysis (CLBMON programs)

The influence of environmental conditions, such as substrate, aspect and slope on plant germination, survival and death, and the effect of multi-year stresses on trends in plant viability for each reservoir ecosystem should be considered at the species and community scale. Key plant species selected for this analysis should be based on professional and local experience, VCTs, and occurrences within the drawdown zone. Local knowledge to select appropriate key species for analysis will be critical,

knowledge of which species to analyse will be based on ecological importance on a community scale (holistic approach). Key plant species to be analyzed should be those that occur within the identified VCT areas of the ALR and KIN. A specific species list selection and rationale of their selection for analysis (i.e., a holistic ecosystem approach, cultural use, ecological importance) will be provided to BC Hydro for review and acceptance prior to analysis. BC Hydro will supply a list of cultural use plants (created in consultation with First Nations), their cultural uses and their occurrence in the drawdown zones of both the KIN and ALR. Cultural plant species could be included for analysis or recommended for future revegetation. Relationship trends will be analyzed between plant species survival (and death) and environmental variables, "reservoir filters" should be considered where the appropriate data are available.

Task 5: Catalogue Reporting

A comprehensive report will be prepared at the end of Year 1 clearly describing data collation and gap analysis methods employed during the program, field data collection recommendations, data analyses, recommendations for future revegetation physical works, and study findings for each Arrow Lakes and Kinbasket Reservoirs which will include but not be limited by:

- an executive summary;
- a glossary;
- an introduction and summary of the relevant programs;
- management questions and hypotheses;
- existing monitoring results summary and physical works data gap analysis resulting from data collation and catalogue creation;
- a detailed summary of the monitoring and works findings as they relate to the ecological hypotheses and the management questions; and
- recommendations for revegetation works (particularly for CLBWORKS-1 Kinbasket and any revegetation on Arrow that relates to Wildlife Physical Works) as a result of observed trends in species survival as a result of the inundation regime and other explanatory variables.
- recommendations for opportunistic modifications to operations in both reservoirs.

Reports will follow the standard format that has been developed for WUP studies. All reports will be provided in hard-copy and as Microsoft Word and Adobe Acrobat (*.pdf) format, and all maps and figures will be provided either as embedded objects in the Word file or as separate files. All map data, including meta data, will also be provided electronically in ARC GIS compatible format. Data (including photographic time-series) will be maintained in a relational database with a full description of the contents of each attribute.

Task 6: Presentation and Stakeholder Meeting

Preparation and delivery of the catalogue results and study recommendations to a technical stakeholder working group (location could potentially be in southern BC) may be required after the first year of the study in 2016 and the second year in 2020. This task includes the preparation of a PowerPoint presentation, liaison with BC Hydro, and attendance at both meetings.

2.4 Budget

Total Program Cost: $224,136

3 References

BC Hydro. 2007. Columbia River Project Water Use Plan. BC Hydro Generation, Burnaby B.C. 41 pp.

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