

**Columbia River Project Water Use Plan  
Monitoring Program Terms of Reference**

**COLUMBIA RIVER WHITE STURGEON  
MANAGEMENT PLAN**

- **CLBMON-23 Mid Columbia River Sturgeon Egg Mat Monitoring and Feasibility Study**

**June 15, 2007**

## **Terms of Reference for the Columbia River Project Water Use Plan Monitoring Programs Columbia River White Sturgeon Management Plan**

### **1.0 OVERVIEW**

This document presents Terms of Reference for the effectiveness monitoring programs and physical works for the Columbia River White Sturgeon Management Plan (Table 1). These programs will provide essential baseline data against which to monitor outcomes of the recommended operational changes in addition to providing information on which to base future operating decisions. This document provides detailed Terms of Reference for the following programs:

#### **Monitoring Programs:**

- 1) CLBMON-19 Kinbasket Sturgeon Inventory and Habitat Use: A 3-year program to determine if white sturgeon are present in Kinbasket Reservoir, what the status of that population is, and what habitat attributes exist in the reservoir to support white sturgeon.
- 2) CLBMON-20 Mid Columbia River Spawning Habitat Assessment: A 2-year program to establish spawning flows and spawning habitat requirements for possible habitat rehabilitation.
- 3) CLBMON-21 Mid Columbia River Juvenile Sturgeon Detection and Habitat Program and Tracking of Existing Sonic Tagged Sturgeon: A 10-year program to detect and monitor juvenile white sturgeon presence and habitat use in the mid Columbia River. The program is also intended to determine whether sufficient habitats exist to allow for recruitment of larvae and evaluate whether seasonal flow releases provide for suitable habitat for successful recruitment.
- 4) CLBMON-23 Mid Columbia River Sturgeon Egg Mat Monitoring and Feasibility Study: A 10-year program to assess the distribution of sturgeon eggs, and assist in setting a seasonal minimum flow and evaluating the impacts of this flow on egg and larval stranding.
- 5) CLBMON-24 Mid Columbia River Sturgeon Genetics: A 1-year study to further investigate stock differentiation of the Arrow Lakes Reservoir and Lower Columbia River white sturgeon.
- 6) CLBMON-25 Kinbasket Juvenile Sturgeon Detection and Habitat Use: A 6-year program to monitor patterns of habitat use by juvenile white sturgeon in Kinbasket Reservoir
- 7) CLBMON-26 Kinbasket Sturgeon Recolonization Risk Assessment and Habitat Suitability: A 3-year program to investigate the ecological risks of conservation aquaculture for white sturgeon in Kinbasket Reservoir.
- 8) CLBMON-27 Mid Columbia River Sturgeon Incubation and Rearing Study: A 2-year study to evaluate the impacts of low water temperature on sturgeon egg and larval development.
- 9) CLBMON-28 Lower Columbia River Adult Sturgeon Population Monitoring: A 13-year study to monitor the abundance, biological characteristics, and reproductive status of white sturgeon in the lower Columbia River to determine operational factors influencing population processes and to ensure that implementation of any physical works does not decrease their abundance.

- 10) CLBMON-29 Lower Columbia River Juvenile Sturgeon Monitoring: A 10-year study to monitor the relative abundance, distribution, and patterns of habitat use of juvenile white sturgeon in the lower Columbia River in relation to discharges from Hugh Keenleyside Dam.
- 11) CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events: A 2-year study to create a plan and assess on an opportunistic basis the high flow events in the lower Columbia River on egg, larval, and juvenile sturgeon survival.

**Physical Works:**

- 1) CLBWORKS-24 Mid Columbia Experimental Aquaculture: An experimental aquaculture program to provide juveniles for assessing flow treatments on larval and juvenile sturgeon survival and impacts of Arrow operations on juvenile habitat availability, suitability, and survival.
- 2) CLBWORKS-25 Mid Columbia Sturgeon Conservation Aquaculture: Conservation aquaculture to support the sturgeon population until such a time as stock abundance/age structure and habitat conditions can support a self-sustaining population
- 3) CLBWORKS-26 Mid Columbia Sturgeon Upgrade Hatchery: upgrade existing facilities at the Kootenay Hatchery to support CLBWORKS-24 and CLBWORKS-25 above.
- 4) CLBWORKS-27 Lower Columbia Sturgeon Physical Works: Physical works options to address sturgeon recruitment failure in the lower Columbia River.
- 5) CLBWORKS-28 Planning and Assessment of WSG Turbidity: a feasibility study to recommend physical works options to address credible hypotheses for sturgeon recruitment failure in the lower Columbia River
- 6) CLBWORKS-34 Lower Columbia Sturgeon Aquaculture Program: Conservation aquaculture to support the sturgeon population until such a time as stock abundance/age structure and habitat conditions can support a self-sustaining population

**Table 1 Columbia River White Sturgeon Management Plan Monitoring Program Terms of Reference Submission Information**

Name of Monitoring Program	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date
CLBMON-19 Kinbasket Sturgeon Inventory and Habitat Use	Schedule F: 1.a	No	No	
CLBMON-20 Mid Columbia River Spawning Habitat Assessment	Schedule F: 1.b	No	No	
CLBMON-21 Mid Columbia River Juvenile Sturgeon Detection and Habitat Program and Tracking of Existing Sonic Tagged Sturgeon	Schedule F: 1.c and 1.d	Yes	No	June 2007
CLBMON-23 Mid Columbia River Sturgeon Egg Mat Monitoring and Underwater Videography Feasibility	Schedule F: 1.e	Yes	No	June 2007
CLBMON-24 Mid Columbia River Sturgeon Genetics	Schedule F: 1.f	No	No	

CLBMON-25 Kinbasket Juvenile Sturgeon Detection and Habitat Use	Conditional	No	No
CLBMON-26 Kinbasket Sturgeon Recolonization Risk Assessment and Habitat Suitability	Conditional	No	No
CLBMON-27 Mid Columbia River Sturgeon Incubation and Rearing Study	Schedule F: 1.g	No	No
CLBMON-28 Lower Columbia River Adult Sturgeon Population Monitoring	Schedule F: 1.h	No	No
CLBMON-29 Lower Columbia River Juvenile Sturgeon Monitoring	Schedule F: 1.i	No	No
CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events	Schedule F: 1.j	No	No
CLBWORKS-24 Mid Columbia Experimental Aquaculture	Schedule F: 3.a	No	No
CLBWORKS-25 Mid Columbia Sturgeon Conservation Aquaculture	Schedule F: 3.b	No	No
CLBWORKS-26 Mid Columbia Sturgeon Upgrade Hatchery	Schedule F: 3.c	No	No
CLBWORKS-27 Lower Columbia Sturgeon Physical Works	Conditional	No	No
CLBWORKS-28 Planning and Assessment of WSG Turbidity	Schedule F: 2.a	No	No
CLBWORKS-34 Lower Columbia Sturgeon Aquaculture Program	Schedule F: 3.b	No	No

## **Monitoring Study No. CLBMON-23**

### **Mid Columbia River White Sturgeon Egg Mat Monitoring and Underwater Videography Feasibility Study**

#### **1.0 MONITORING PROGRAM RATIONALE**

##### **1.1 Background**

###### **1.1.1 Mid-Columbia River White Sturgeon Management Plan**

The Columbia Water Use Plan Consultative Committee (WUP CC) and Fish Technical Subcommittee (FTSC) asked the Upper Columbia White Sturgeon Recovery Initiative Technical Working Group (UCWSRI TWG) to develop final recommendations related to treatment options and monitoring for white sturgeon recovery within a recommended funding envelope. The resulting recommendation involved a 4-phase management plan (Figure 1), extending over 10 years, aimed at better understanding habitat capabilities for juvenile white sturgeon in the mid Columbia River and the potential for Arrow Lakes Reservoir or Kinbasket Reservoir to become a sturgeon recovery or failsafe area with the help of conservation aquaculture. The plan was designed to inform on key hypotheses regarding potential habitat changes in the mid Columbia River that may have contributed to recruitment failure, and to focus on habitat capacity and early life history habitat requirements (spawning, incubation, and rearing), where bottlenecks to production are thought to be occurring. A seasonal minimum flow treatment was proposed as a possible means of improving spawning conditions and the survival of naturally spawned individuals during the egg and larval stages. An experimental aquaculture program was proposed to help address key uncertainties regarding the availability and suitability of juvenile rearing habitat in the mid Columbia River in the short term. Over the long term, a conservation aquaculture program in either Arrow Lakes or Kinbasket reservoirs would help to support the population until such a time as stock abundance, age structure, and habitat conditions can support a self-sustaining population.

The work plan is designed in phases to allow the necessary flexibility in the allocation of annual funds for research, experimental treatments, and monitoring to ensure the program is responsive to future learnings and related changes in priorities. This objective will be facilitated through annual overview reviews and periodic comprehensive reviews of the program. For example, a decision to either implement flow tests in the mid Columbia River (if monitoring supports this decision) or to direct all or part of the conservation aquaculture effort to Kinbasket Reservoir will be made once the initial phases of monitoring results are analyzed and reviewed.

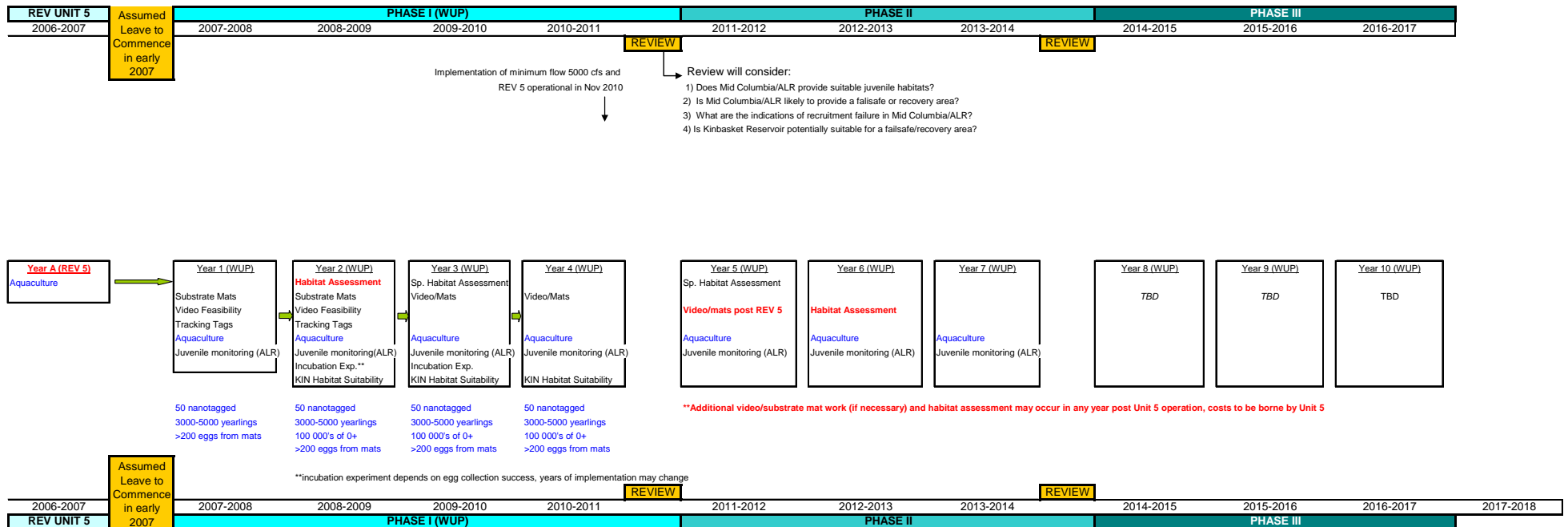
The work plan specifically addresses three key uncertainties related to white sturgeon recovery:

- 1) Can stocking of yearling (or younger) sturgeon provide for rebuilding of the Arrow sub-population and mitigate reservoir impacts?

- 2) Can stocking of yearling (or younger) sturgeon provide for either recovery of a self-sustaining sub-population or development of a failsafe (non-reproducing) population in the Arrow or Kinbasket reservoirs?
- 3) Can recruitment failure in the mid Columbia be addressed by operational changes?

The FTSC and UCWSRI TWG recognized that a substantial monitoring program would need to accompany the plan to address these key uncertainties. Research and monitoring programs, including studies to define sturgeon spawning and rearing habitat capability in the mid Columbia River and Kinbasket Reservoir, were considered essential for making decisions related to the need for seasonal minimum flow treatments, the magnitude and duration of flow treatments, and hatchery supplementation. The goal of these studies is to determine reasons for recruitment failure and to assess the effectiveness of treatment options in eliciting a detectable recruitment signal and establishing sustainable recruitment.

Figure CLBMON-23-1 Proposed mid Columbia River and Kinbasket Reservoir Water Use Plan White Sturgeon 10-Year Implementation Plan



### 1.1.2 White Sturgeon Egg Mat Monitoring and Underwater Videography Feasibility Study

Canadian Columbia River populations of white sturgeon were listed as endangered under the Species at Risk Act (SARA) in 2006. The majority of the remaining population is found in the lower Columbia River downstream of the Hugh L. Keenleyside Dam (HLK), with a smaller population of an estimated 50 fish living in the Arrow Lakes Reservoir upstream to Revelstoke Dam (Golder 2006).

BC Hydro has funded a number of investigations of white sturgeon in Arrow Lakes Reservoir. In 1999, a small number of white sturgeon were tracked to the Columbia River downstream of Revelstoke Dam. The presence and sexual maturity of these fish was interpreted as being related to spawning activity (RL&L Environmental Services Ltd. 2000, Golder Associates Ltd. 2003), and capture of fertilised eggs confirmed successful spawning. Spawn monitoring in 2003 and 2006 also resulted in collection of fertilised eggs and confirmation of spawn timing in late July/early August. The work documented the location of a second spawning site for white sturgeon within the Canadian portion of the Columbia River and the only known spawning site for the Arrow Lakes Reservoir fish.

Annual spawn monitoring below Revelstoke Dam is required under the terms of the Columbia River Project Water Licence Order to document spawning events, timing, frequency, egg deposition, and habitat conditions. Due to the low numbers of aging fish in Arrow Lakes Reservoir, it is likely that spawning events do not occur every year and events will gradually decline in frequency over time. To date, spawn monitoring has occurred when tagged fish have been located close to the spawning site. However, all sonic tags will expire by 2008 and the deployment of additional tags is considered undesirable, as it would require additional capture and stress of the few remaining adults. As an alternative, testing the feasibility of underwater videography to detect presence of adults in the spawning area has been proposed. Conducting spawn monitoring with substrate mats will also allow for the collection and on-site incubation of eggs for rearing and release in the mid Columbia River as part of the aquaculture program.

Sampling for eggs in this habitat is difficult and, to date, has been restricted to the margins of the river (RL&L Environmental Services Ltd. 2000 and 2001, Golder Associates Ltd. 2001 and 2003). There is a need to sample additional habitats to assess the distribution of incubation areas and to understand whether operations are dewatering significant numbers of white sturgeon eggs. There is also a need to effectively monitor white sturgeon spawning events, since they do not occur every year. This Terms of Reference addresses the feasibility of underwater videography (or potentially other remote sensing methods) as a less-intrusive alternative to assess staging of spawners and to record actual spawning events. Since spawning apparently does not occur every year, it would be beneficial to direct any water management costs and study efforts to those times when spawning fish are using the spawning area. During 2007-08 and 2008-09, existing sonic tagged adult sturgeon will be monitored to determine if fish are moving into previously observed staging and spawning sites. This work will be

completed under CLBMON-21, Mid Columbia River Juvenile Sturgeon Detection and Habitat Use Program and Tracking of Existing Sonic Tagged Sturgeon. During those two years, the tracking component of CLBMON-21 should provide movement information to assist with planning for egg mat and videography equipment deployment. If no adult movement into the area is detected, a decision to defer the work may be made jointly between UCWSRI TWG and BC Hydro.

## 1.2 Management Questions

The riverine section of the Columbia River below Revelstoke Dam is the only known spawning site for the white sturgeon sub-population in Arrow Lakes Reservoir. The key management uncertainties are related to how operation of Revelstoke Dam and Arrow Lakes Reservoir affect the quantity and quality of white sturgeon spawning and incubation habitat in this section of the Columbia River. Ultimately, there are a number of questions regarding whether operations can be adjusted to improve or enhance spawning and incubation conditions, and whether physical works can be implemented to improve condition; however, at present the management questions are related to timing and location of white sturgeon spawning, distribution of eggs, and relative incubation success.

The fundamental management questions to be addressed through this study are:

1. Where are the primary white sturgeon incubation sites below Revelstoke Dam?
2. How do dam and reservoir operations affect egg and larvae survival in this area? Specifically, do significant numbers of eggs become dewatered as a result of operations?
3. Can underwater videography or other remote sensing methods be used to effectively monitor staging and spawning of white sturgeon?
4. What is the most effective method for monitoring spawning of white sturgeon?
5. Can modifications be made to operation of Revelstoke Dam and Arrow Lakes Reservoir to protect or enhance white sturgeon incubation habitat?

## 1.3 Management Hypotheses

This study is set up as a descriptive rather than experimental approach, and as such, it is designed to provide baseline information rather than test specific management hypotheses or measure biological response to different treatments. The study is nevertheless expected to critically inform decisions regarding changes in operation and their effect on white sturgeon spawning and incubation habitat.

Habitat data collected from those spawning and incubation areas identified during this study will be used to determine whether operations currently reduce

spawning and incubation habitat availability and suitability, and whether modified operations can be expected to improve conditions.

#### **1.4 Key Water Use Decisions**

During development of the Columbia River Water Use Plan (WUP), efforts were made to explore the relationship between white sturgeon spawning, incubation, and rearing habitat and operation of Revelstoke Dam and Arrow Lakes Reservoir, with the intent of recommending alternative operations within the constraints imposed by the WUP process. The WUP Fish Technical Subcommittee recommended that providing a periodic flow augmentation during sturgeon spawning and incubation could potentially benefit white sturgeon recruitment. The magnitude and duration of the seasonal flow augmentation was not specified in detail in the WUP. Instead, a water budget was proposed with an economic cap of \$5 million per 10 years to allow for provisions of a volume of water that can be allocated in a manner best suited to spawning and incubation needs of white sturgeon. It was envisioned that information collected during the first few years of the monitoring program would be used to decide if flow augmentation is a suitable option and, if so, determine an appropriate water allocation schedule in subsequent years. In a subsequent review of the program, prompted by the initiation of the Revelstoke Unit 5 project, the UCWSRI TWG made recommendations to amend the 10 year monitoring plan in consideration of the potentially confounding effects of Revelstoke Unit 5 operations and to provide more scientifically defensible results. The TWG recommended that all flow changes be implemented at or after initiation of Unit 5. The TWG supported synchronising commencement of the  $142 \text{ m}^3\text{s}^{-1}$  minimum flow with Unit 5 operation and deciding on implementation of any flow treatments during the spawning period during a program review in 2011. This approach will allow for four years of baseline data collection prior to any operational change and a more robust pre-treatment data set.

The present study, which will explore methods for effectively monitoring spawning events below Revelstoke Dam and describe the distribution of incubation sites, will provide significant information to decision makers on how best to allocate water for sturgeon spawning and incubation.

## **2.0 MONITORING PROGRAM PROPOSAL**

### **2.1 Objective and Scope**

The primary objectives of this monitoring program are to:

1. Assess sturgeon incubation sites and conditions downstream of Revelstoke Dam,
2. Relate egg stranding risk to discharge from the dam and water elevation of Arrow Reservoir,
3. Assess the feasibility of underwater videography or other remote sensing techniques for monitoring presence of white sturgeon spawners,

4. Select and implement the most effective method (egg mats or videography or other remote sensing) for ongoing monitoring of spawning of white sturgeon, and
5. Provide input to recommendations for the water allocation schedule for white sturgeon spawning and incubation.

The program will use information on adult movements and timing in 2007-08 and 2008-09 provided by CLBMON-21 (Juvenile Sturgeon Detection and Habitat Use Program and Tracking of Existing Sonic Tagged Sturgeon) to decide if spawning is likely to occur during those two years. If fish begin to move into the area, the videography system can be activated. The scope of the program is to collect information on spawning incidence and timing, using the mats and underwater video system, and to assess methodological capabilities and incubation risks associated with operational scenarios.

## **2.2 Approach**

The general approach of this monitoring program will be to monitor sturgeon spawning and egg deposition, to assess the feasibility of underwater videography for detecting white sturgeon spawners, and to decide on the most effective method for monitoring white sturgeon spawning events. The study has four components: substrate mat studies below Revelstoke Dam, assessment of the feasibility of videography or other remote sensing techniques as a monitoring tool, design and implementation of a long-term spawn monitoring program, and provision of information for decision makers regarding water allocation during white sturgeon spawning and incubation.

## **2.3 Tasks**

### **2.3.1 Task 1: Project Planning and Coordination**

Project coordination involves the general administrative and technical oversight of the monitoring program, which will include, but not be limited to 1) budget management, 2) study team selection, 3) logistic coordination, 4) technical oversight in field and analysis components, and 5) facilitation of data transfer among other investigations associated with the Columbia River White Sturgeon Management Plan.

A safety plan must be developed and submitted to the BC Hydro contact, for all aspects of the study involving field work, in accordance with BC Hydro procedures and guidelines. Specific safety training may be required.

### **2.3.2 Task 2: Field Studies – Spawn Monitoring and Feasibility of Underwater Videography**

The initial field study program for videography feasibility is scheduled to occur in 2007 and 2008, while there are active sonic tags in adult fish. Spawn monitoring using substrate egg mats will occur annually from 2007-2010 as a means to monitor egg deposition, as well as to collect eggs for on-site incubation and eventual release into the mid Columbia River. This study component will allow for

a genetic contribution of Arrow Lakes Reservoir fish to the aquaculture program. In previous studies, a grid of mats has been distributed above and below the expected spawning location and monitored regularly to assess spawning incidence and timing and have generally sampled the channel margins (Golder 2006). In this program, effort should be made to also assess the degree of egg stranding associated with current operations and distribute mats over a greater area to sample a greater cross section of the river channel and overcome a bias toward the channel edge. Following the first two years of monitoring, the UCWSRI TWG and BC Hydro biologists will decide whether to conduct annual monitoring using the mats or videography (or other), or some combination of the two methods.

### **2.3.3 Task 3: Data Analysis and Reporting**

The data will be analysed to assess the incidence and timing of spawning events, the incidence of egg stranding, and the relative success of incubation. Catch per unit effort, and descriptive statistical analyses of the mat samples will be compared between years and with other populations to provide a qualitative assessment of spawning success. With the advent of minimum flow releases, and possibly seasonal flow treatments (if a decision is made to implement these flow), the background data collected in the first phase of work can be used to determine if there are changes in spawning and incubation success, provided adequate numbers of spawners remain in the population. A key component of the study is to determine if the videography can be used to document the incidence and timing of spawning events.

Project reporting will consist of one annual data report for each year of the program and a final report at the conclusion of Year 2. Separate reports will be prepared for the egg mat monitoring and the videography. Data reports should include a brief description of methods, presentation of the data collected that year, and the results of basic analyses. For the videography study a DVD or other applicable format may be included to adequately describe the study findings. Final reports will include:

- (a) an executive summary;
- (b) a description of the methods employed;
- (c) a data summary;
- (d) a comparison of results between years and with other populations;
- (e) a discussion of how the results relate to the key management questions;  
and
- (f) recommendations as to changes in sampling, monitoring and assessment of flow treatments, and program continuation.

Reports will follow the standard format that is being developed for WUP monitoring programs. 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.

## **2.4 Interpretation of Results**

The results of this study will be used to confirm spawning and incubation locations for subsequent habitat assessments (i.e., CLBMON-20 White Sturgeon Spawning Habitat Assessment). Egg mat data will be used to determine the incidence and timing of spawning events, and will be analyzed to determine incidence of egg stranding and incubation success. The videography component of the work will test the suitability of the methodology for documenting presence of adult fish in the spawning area.

The information collected in this monitoring program is descriptive rather than quantitative and is aimed at providing baseline information rather than test specific management hypotheses or measure biological response to different treatments. Results will be used to address the management questions outlined in Section 1.2.

## **2.5 Schedule**

This monitoring program will occur during the first 10 years of implementation of the Columbia River Water Use Plan. The first two years of the program will be implemented in 2007 and 2008 to coincide with the active life of remaining sonic implanted in adult sturgeon. Annual reviews of the progress by BC Hydro and the UCWSRI TWG may result in changes to aspects of the implementation. A full review of the mid Columbia White Sturgeon Monitoring Plan (WSMP) will occur in 2011, following the initial phase and prior to implementation of any flow changes. Decisions regarding components required after 2010 in the next phase of the program will be based on the results of initial monitoring data.

A proposed annual schedule is provided below. Bullet i) is not part of this Terms of Reference, but instead is incorporated into the Juvenile Sturgeon Detection and Habitat Use and Tracking of Existing Sonic Tagged Sturgeon (CLBMON-21).

- i) Adult telemetry monitoring from April to the conclusion of spawning.
- ii) Videography system installation or other remote sensing apparatus – June/July
- iii) Videography system/or other remote sensing apparatus monitoring, maintenance, and adjustment from June to August
- iv) Egg mat installation and monitoring with potential egg retrieval for aquaculture - July and August
- v) Egg mat and videography system removal from August to September
- vi) Data analyses from October to December
- vii) Report preparation from December to March

The program recommended by the UCWSRI TWG has three scheduled comprehensive reviews of mid Columbia sturgeon data. Depending on the study results, the review process may result in redirection of recovery work to Kinbasket reservoir, and/or rely on conservation culture to maintain the Arrow Reservoir as a failsafe area. The first review in 2011 will consider the implications of the baseline data results from juvenile monitoring and habitat assessments, spawn and incubation monitoring and habitat assessments, adult sonic telemetry, and incubation experiments. The second review in 2014 will consider similar study results associated with minimum flow provision and possibly preliminary seasonal flow treatments or stocking efforts in Kinbasket Reservoir, while the final review in 2017 will assess the results associated either with seasonal flow treatments or efforts in Kinbasket Reservoir

## **2.6 Budget**

Table CLBMON-23-1 provides annual budget estimates assuming a 2% rate of inflation and a 5 % contingency for the duration of the program. During Years 1 and 2 (2007 and 2008), the egg mat sampling and videography work will be conducted. Before Year 3 of the program (2009), the UCWSRI TWG and BC Hydro biologists will determine the most effective and efficient means of continuing to monitor spawning events. Spawning could be monitored using either egg mat monitoring or videography, or a combination of the two methods. The budget presented assumes that starting in 2009, spawning will be monitored using egg mats. If videography proves a feasible methodology, the monitoring budget will change.

## **3.0 REFERENCES**

Golder Associates Ltd. 2006. A synthesis of white sturgeon investigations in Arrow Lakes

Reservoir, B.C. 1995-2003. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 041480016F: 61 p. + plates +11 app.

Golder Associates Ltd. 2001. White sturgeon investigations in Arrow Reservoir and the Columbia River, B.C., 2001 study results. Data report prepared for BC Hydro, Castlegar, B.C.

Golder Associates Ltd. 2003. White sturgeon investigations in Arrow Lakes Reservoir B.C., 2002 - 2003 study results. Data report prepared for BC Hydro, Castlegar, B.C.

R L & L Environmental Services Ltd. 2000. White sturgeon investigations in Arrow Reservoir and Columbia River, B.C., 1999 study results. Report prepared for BC Ministry of Environment, Lands and Parks, Nelson, B.C.

R L & L Environmental Services Ltd. 2001. White sturgeon investigations in Arrow Reservoir and Columbia River, B.C., 2000 study results. Data report prepared for BC Ministry of Environment, Lands and Parks, Nelson, B.C.