Columbia River Project Water Use Plan

Columbia River White Sturgeon Management Plan
Annual Report: 2009

- CLBMON-19 Kinbasket Reservoir White Sturgeon Inventory and Habitat Use Assessment
- CLBMON-20 Mid Columbia River White Sturgeon Spawning Habitat Assessment
- CLBMON-21 Mid Columbia River Juvenile Sturgeon Detection and Habitat Program and Tracking of Existing Sonic Tagged Sturgeon
- CLBMON-23 Mid Columbia River Sturgeon Egg Mat Monitoring and Feasibility Study
- CLBMON-24 Mid Columbia River Sturgeon Genetic
- CLBMON-25 Kinbasket Reservoir Juvenile Sturgeon Detection and Habitat Use Program
- CLBMON-26 Kinbasket Sturgeon Recolonization Risk
- CLBMON-27 Mid Columbia River Sturgeon Incubation and Rearing
- CLBMON-28 Lower Columbia Adult Sturgeon Population Monitoring
- CLBMON-29 Lower Columbia Juvenile Sturgeon Detection
- CLBMON-30 Lower Columbia Opportunistic Assessment of High Flow Events
- CLBMON-54 Mid Columbia River Effects of Flow Changes on Incubation and Early Rearing Sturgeon
- CLBWORKS-24 Mid Columbia River White Sturgeon Experimental Aquaculture
- CLBWORKS-25 Mid Columbia River White Sturgeon Conservation Aquaculture
- CLBWORKS-26 Mid Columbia River White Sturgeon Upgrade Hatchery
- CLBWORKS-27 Lower Columbia Bentonite Addition Experiment
- CLBWORKS-26 Lower Columbia Planning and Assessment of WSG Turbidity
- CLBWORKS-34 Lower Columbia River White Sturgeon Conservation

Conditional Water Licences for Kinbasket storage (27068 and 39432), Mica diversion (39431), Revelstoke diversion and storage (47215), and Arrow storage (27066)

31 May 2010
1 Introduction

This annual report provides a summary of the status and results of monitoring programs and physical works being implemented under the Columbia River White Sturgeon Management Plan of the Columbia River Water Use Plan (WUP) to 30 May 2009, as per the Columbia River Order under the Water Act, dated 26 January 2007. There are 12 monitoring programs and 6 physical works included within this Management Plan and are listed below:

- CLBMON-19 Kinbasket Reservoir White Sturgeon Inventory and Habitat Use Assessment
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2 Background

The water use planning process for BC Hydro’s Columbia River project was initiated in August 2000 and completed in June 2004. The conditions proposed in the WUP for the operation of the project reflect the June 2004 consensus recommendations of the Columbia River WUP Consultative Committee (CC).
In July 2006, the Columbia River Draft WUP was submitted to the Comptroller of Water Rights (CWR). The draft WUP was sent out to regulatory agencies, First Nations and interested stakeholders for review. In January 2007, the CWR approved the final WUP and issued an Order to BC Hydro to implement the conditions proposed in the Columbia River WUP and prepare the monitoring programs and physical works Terms of Reference (TOR).

An addendum to the Columbia River WUP was submitted to the CWR in July 2007 in response to the Environmental Assessment Certificate issued for the Revelstoke Unit 5 Project. The addendum proposes additional terms and conditions for the Columbia River WUP, as recommended by the Revelstoke Unit 5 Core Committee, to address incremental impacts of the operation of the fifth generating unit at Revelstoke Dam.

In August 2007, the CWR accepted the Columbia River Project WUP Addendum resulting from the Revelstoke Unit 5 Project, and issued amendments to the Columbia River Implementation Order to include the commitments made by BC Hydro to undertake additional monitoring programs and physical works associated with the Revelstoke Unit 5 Project.

The following table outlines the dates that TOR for the Columbia River White Sturgeon Management Plan have been submitted to and approved by the CWR.

<table>
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<tr>
<th>Monitoring Program TOR</th>
<th>Order Clause</th>
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<td>CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events</td>
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As outlined in the Columbia River WUP, the Consultative Committee recommended a full review of the Columbia River Water Use Plan 13 years after implementation, unless results of the monitoring program suggest an earlier review is appropriate or significant risks are identified that could result in a recommendation to change operations.

BC Hydro will convene a multi-party panel five years after commencing the implementation of this WUP to evaluate the effectiveness of operations and physical works in meeting the stated objectives for Arrow Lakes Reservoir and the lower Columbia River. The outcomes from this process will be used to assess any potential need to review the Arrow Lakes Reservoir component of this WUP. If a replacement Non-Treaty Storage Agreement (NTSA) is negotiated within this 5-year period, it is also recommended that agreement provisions and implications be reported out through this panel. Signing of a new NTSA is not a trigger for panel evaluation or a review of this Water Use Plan recommendation to change operations.

3 Schedule

The following table (Table 3-1) outlines the current schedule for the monitoring programs and physical works being delivered under the Columbia River White Sturgeon Management Plan of the Columbia River Water Use Plan.

<table>
<thead>
<tr>
<th>Project Description</th>
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Table 3-1: Schedule of Columbia River WUP Monitoring Programs and Physical Works Implementation under the Columbia River White Sturgeon Management Plan

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Legend:
- ** = Program to be undertaken/initiated in identified year
- * = Project is underway
- ✓ = Program completed for the year
- * = Program started, but encountered operational or hydrological delays
- C** = Program is on the conditional list
- C = ToR to be resubmitted in summer 2009
4 Columbia River WUP Monitoring Programs - Columbia River White Sturgeon Management Plan

This section summarizes the status of the monitoring programs being implemented under the Columbia River White Sturgeon Management Plan of the Columbia River Water Use Plan, as per the Order under the Water Act, dated January 26, 2007.

4.1 CLBMON-19 Kinbasket Sturgeon Inventory and Habitat Use

4.1.1 Overview

The Kinbasket Sturgeon Inventory and Habitat Use study is a 3-year investigation into the status and habitat use of white sturgeon in Kinbasket Reservoir and the Columbia River upstream. The study is descriptive in nature, and will include surveys at key locations to capture adult and/or juvenile white sturgeon, record habitat characteristics important to the white sturgeon life cycle, and describe movements of captured adults using ultrasonic telemetry.

The primary objectives of this monitoring program are to assess:

• the presence of white sturgeon in Kinbasket Reservoir,
• whether natural recruitment has occurred, and
• the habitat associations of white sturgeon in Kinbasket Reservoir.

Information obtained through this monitoring program will feed into a subsequent or concurrent evaluation of Kinbasket Reservoir as a recovery/failsafe area for white sturgeon (CLBMON-26) included as part of the Mid Columbia River White Sturgeon Monitoring Plan.

4.1.2 Status

This monitoring program was initiated in June 2008 and is being carried out over three consecutive years. A contract was awarded to CCRIFC in association with the Okanagan Nation Alliance (ONA) and Westslope Fisheries. The final report for Year 2 of this monitoring program is complete and appended to this document.

4.1.3 Interpretation of Data

Three sampling sessions were conducted in 2009: one in the spring (May), one in the summer (July), and one in the fall (September). The spring sampling session was designed to target low Kinbasket Reservoir elevations when natural river confluences would be more apparent. The summer sampling session was designed to target adult white sturgeon in riverine habitats when water temperatures mimicked spawning temperatures (~10°C) of other Columbia sturgeon populations (i.e., Lower Columbia River). Areas selected for sampling in September targeted potential feeding aggregations of sturgeon at the confluence areas of kokanee spawning tributaries. Setlines were the only method used to sample for white sturgeon in the reservoir and were configured as per the Upper Columbia River White Sturgeon Recovery Initiative (UCRWSRI) fish handling manual. Each setline measured 45 m in length with 10 16/0 barbless circle halibut hooks attached at 3.5 m intervals. A total of 237 setlines...
were deployed for 51,165 hook hours. No sturgeon were captured in any of the three sampling sessions. Based on the habitat surveys to date, the best available spawning habitats in Kinbasket Reservoir are at the confluences of Wood and Sullivan Rivers, Surprise Rapids, and the Columbia River upstream of Quartz Creek. The best available juvenile habitats appear to be in the bays of Encampment, Hugh Allen, and Foster Creeks, Windy Bay, the narrows approaching Surprise Rapids and the Columbia River upstream of Donald. Further habitat data will be collected in 2010.

Three sampling sessions are being conducted in 2010. The first is occurring in late May to target river confluences when the reservoir is at its lowest. Consistent with 2008 and 2009, a sampling session is planned for July to target adult white sturgeon in riverine habitats and a final sampling session is planned for September to target potential feeding aggregations of sturgeon at the confluence areas of kokanee spawning tributaries. Any white sturgeon captured will be implanted with an acoustic transmitter. Tagged fish will be monitored using an array of automated receivers anchored at strategic positions within the reservoir to help identify habitat usage. This year represents the final year of this work. A final program report will be submitted in early 2011.

4.2 CLBMON-20 Mid Columbia River Spawning Habitat Assessment

4.2.1 Overview

As part of the monitoring plan recommended for the Arrow Lakes Reservoir sturgeon population, the WUP Consultative Committee identified the need to better understand spawning habitat capability in the mid Columbia River, and how dam and reservoir operations influence the quality and quantity of this habitat. It was recommended that detailed hydrometric surveys be undertaken in the mid Columbia River in locations of known white sturgeon spawning and other locales, as appropriate, to validate assumptions used to decide on and set white sturgeon spawning flow treatments, and determine spawning habitat objectives for sturgeon for future rehabilitation activities.

The Mid Columbia River White Sturgeon Spawning Habitat Assessment is being conducted over a 2-year period to:

1) Assess hydraulic and substrate conditions in locations of known sturgeon spawning immediately below Revelstoke Dam.

2) Relate hydraulic conditions to discharge from the dam and water elevation of Arrow Lakes Reservoir.

3) Assess operations of the dam and the reservoir in providing suitable spawning conditions and incubation for white sturgeon.

4) Provide recommendations for selection of a water allocation schedule for white sturgeon spawning in the mid Columbia River.

The scope of the program is limited to empirical measurements of hydraulics (water depths and velocities) and substrate conditions, post-measurement analysis, and professional judgment. The study will be undertaken over a 2-year period (one year pre-REV5 and one year post-REV5) to allow collection of data over a range of dam discharges and reservoir elevations.
4.2.2 Status

The implementation of this 2-year monitoring program was originally scheduled for 2009 and 2011 but was delayed until 2010 and 2012 to allow coordinated delivery with CLBMON-54 due to similarities in program design and data requirements. A contract was awarded to Golder Associates (Castlegar BC) partnering with ASL environmental in the spring of 2010. Hydraulic modelling will be conducted to develop a 3-dimensional model that will allow accurate prediction of water velocities and flows over the white sturgeon spawning grounds at different reservoir elevations and flows from Revelstoke Dam. Given the complexity of flow conditions in the spawning area (influenced by flow inputs from two large rivers, Columbia and Jordan, and also include a large eddy feature), development of this high resolution numerical 3D flow model will allow the assessment of the effects of flow changes on sturgeon spawning habitat. The 3D numerical model has been previously used with great success to address similar questions at the Waneta Spawning area in the lower Columbia River. The model has the degree of resolution necessary to identify fine-scale changes adjacent to near-bottom areas of the river bed, which are important habitats for white sturgeon spawning, egg incubation, and early rearing. Finally, the 3D model is also is capable of computing sediment properties (suspended sediment concentrations, deposition and erosion). This model will be a valuable tool when considering the long-term nature of sturgeon research programs in the mid Columbia River as it will allow the assessment of present and potential future changes to river hydraulics.

The first field sampling program will occur in early June when Arrow Lakes Reservoir elevations are low enough to not result in backwatering over the spawning grounds. Transects will be run collecting water velocities and depths at three different flow targets from Revelstoke Dam. Flow targets will focus on low (5-10 kcfs), intermediate (20-30 kcfs), and high (50-60 kcfs) discharge levels from Revelstoke Dam. A second field sampling session will occur in Mid July when Arrow Lakes Reservoir is near full pool and is resulting in backwatering over the spawning grounds. The same flow targets from Revelstoke Dam will be evaluated. A detail substrate map of the spawning area will also be developed as part of the July sampling period. The hydraulic model developed as part of this monitoring program work will not only address the management questions for this monitoring program but will allow

4.2.3 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.

4.3 CLBMON-21 Mid Columbia River Juvenile Sturgeon Detection and Habitat Program and Tracking of Existing Sonic Tagged Sturgeon

4.3.1 Overview

This study is being conducted to better understand juvenile white sturgeon habitat capabilities in the mid Columbia River, and the potential for either building a self-sustaining or failsafe population in the Arrow Reservoir. This monitoring program will be conducted over a 10-year period, including pre- and post-flow treatment conditions, to evaluate juvenile survival and the availability and suitability of juvenile habitat downstream of Revelstoke Dam to the downstream end of the Revelstoke Reach (roughly located along a line from Arrowhead to Shelter Bay). Sampling may
need to be undertaken in other areas of Arrow Reservoir depending on study results. This work is to be undertaken primarily through a program to recapture marked fish and assessments of the patterns of habitat use by sampling for and tracking acoustic tagged juveniles released from the existing conservation aquaculture program. Once the habitats occupied by these fish are located, they will be described to define juvenile habitat parameters, and the reach will be surveyed to assess the availability of such habitat. A comparison of the juvenile habitat within the reach, with juvenile habitat utilized by other white sturgeon populations in the upper Columbia River and elsewhere, will contribute to testing the hypothesis that juvenile habitat limitations are critically limiting the survival of juvenile white sturgeon and that juvenile rearing habitat for sturgeon spawned in the mid Columbia area is critically limited.

A second component of the monitoring program is the tracking of existing sonic tagged adult sturgeon for the duration of the life of their tags. This work is expected to provide improved knowledge of the timing of movements of adult fish into staging and spawning areas near Revelstoke Dam. These timing data will assist other adult sturgeon monitoring projects, including spawn monitoring and testing of techniques for identifying spawning behaviour and events, as well as the description of spawning habitat conditions under varying flow conditions. Since most of the adult tags are being tracked with the same equipment used to monitor tagged juvenile sturgeon, this monitoring component is included as part of the juvenile monitoring program.

4.3.2 Status

The first year of this monitoring program was initiated in April 2007 under a 2-year contract to Golder Associates Ltd. (Castlegar). In spring of 2009, BC Hydro explored the option of direct awarding this work to First Nations. Statements of qualifications were received, and three First Nations were invited to submit proposals to undertake this work for a 2-year period. A 2-year contract was awarded to the Okanagan Nation Alliance in partnership with Golder Associates Ltd. The 2009 data report is complete and has been appended to this annual report.

4.3.3 Interpretation of Data

Year 1 (2007-2008) – Prior to the release of 4000 sub-yearling juvenile white sturgeon (including 50 with sonic tags) in the mid Columbia River in early May 2007, a series of 18 VR2W receivers was deployed in the river between Revelstoke Dam and Beaton Flats/Galena Bay. Seven VR2W download and maintenance sessions were conducted from May 2007 to March 2008, in addition to five mobile tracking sessions for both sonic tagged juveniles and adults. The general movement pattern exhibited by sonic-tagged juvenile white sturgeon was a rapid downstream movement after release until lower velocity habitats were encountered. Movements then generally became less rapid and fish often spent longer periods of time in specific areas. Gill net sampling and habitat measurements were undertaken in the fall and winter in conjunction with mobile tracking in an effort to capture juvenile white sturgeon to assess growth, survival, and habitat use; however, weather and adverse site conditions hampered success of capture and, in some cases, curtailed sampling effort.

Of the six remaining active coded pingers on adult sturgeon, five were detected by the VR2W array. The furthest upstream detection of a sonic-tagged adult was about 3 km above Tank Creek in August, with the fish subsequently moving back
downstream to Beaton Flats. None of the sonic tagged adults exhibited typical spawning movements (i.e., moving to the Big Eddy/golf course area in late July and August) and the movements detected were likely feeding related.

Year 2 (2008-2009) – A total of 396 hours of short duration (night time) gill net effort and 246 hours of overnight gill net effort resulted in a total capture of four hatchery released juvenile white sturgeon. Growth of these fish since release from the hatchery was low. This is considered likely the result of either low prey availability in the upper portions of Arrow Reservoir or that forage efficiency by juvenile white sturgeon may be lower in a reservoir environment than in a riverine system. However, results from this work to date should be interpreted with caution due to the low sample size of recaptured juveniles. The low catch of juvenile white sturgeon in 2008 and low growth exhibited by these fish should not be considered to necessarily mean that survival is also low. Further refinement of capture methods combined with results from the tracking portion of this work will hopefully result in increased juvenile captures over the next several years.

Hatchery reared juveniles released near higher velocity habitats below Revelstoke Dam in 2008 exhibited rapid downstream movements until they encountered deeper, lower velocity habitats in downstream areas, followed by an overall reduction in movements. This could suggest an active selection for deeper, lower velocity habitat and an apparent avoidance of higher velocity habitats in the middle Columbia River. Habitat parameters within areas inhabited by juvenile white sturgeon in the middle Columbia River were typically over 10 m in depth, with fine substrates, and low velocities (less than 0.2 m/s in 2008). Sonic-tagged juvenile white sturgeon in the middle Columbia River initiated nocturnal movements, which are also associated with periods of decreased flow from Revelstoke Dam. Results indicated a significant relationship between diel movements and Revelstoke Dam discharge, but with substantial variability. Both upstream and downstream movements were observed to show similar diel patterns. The areas with the highest sustained presence of sonic-tagged juveniles were located between Wells Creek (rkm 220) and Crawford Creek (rkm 189). Higher use of the more upstream stations from Salmon Rocks (rKm 223.5) was observed in 2008 compared to 2007. The higher water surface elevations of Arrow Reservoir and resultant lower velocities in 2008 may have been related to the increased use of these upstream sites.

There are currently no adult white sturgeon with active transmitters in the Arrow Reservoir. Sonic-tagged adult white sturgeon were not detected during mobile tracking surveys in 2007 near the spawning area (upstream of Big Eddy) or in 2008 near Mulvehill Creek. Of the 26 adults implanted with sonic tags in Arrow Reservoir since 1997, six transmitters may have been active during the first two years of this study (5 detected in 2007). However, no adults were detected in 2008. The White Sturgeon Technical Working Group in discussions with BC Hydro representatives have decided that tagging additional adults in the Arrow Reservoir would be important to gaining further insight into spawning related movements. A plan will be developed within the group to identify numbers of fish and available resources to capture and tag these adults.

Year 3 (2009-2010) – In year 3, two adjustments were made to the sampling design for this monitoring program based on results from the first two years. Due to low recapture success of juvenile sturgeon stocked from the hatchery program, an alternate gear type (modified set lines) was used in addition to gill nets to attempt to recapture higher number of juveniles. In total, 521 hours (36 net-units) of short
duration (night time) gill net effort and 1085 hook-hours of set line effort resulted the
capture of two juvenile white sturgeon in gill nets. Although juveniles captured in
2008 and 2009 were smaller and grew slower than their lower Columbia River
counterparts, they were in adequate condition (mean relative weight = 87%; n = 6).

A second adjustment was made to the release technique for the acoustic tagged
juveniles to help identify important habitats based on movement patterns. In 2009,
sonic-tagged juvenile white sturgeon were released in groups of 10 at five different
locations that were 10 km apart moving downstream from Revelstoke. This differed
from 2007 and 2008 when fish were all released at one upstream location near
Revelstoke Dam. This was conducted to identify important habitats as juveniles
released in 2007 and 2008 in upstream locations dispersed downstream rapidly
following release and ceased movement when suitable habitat was encountered. In
2009, juveniles released at more upstream locations (<20km downstream of
Revelstoke) exhibited rapid downstream movement to lower velocity habitats, and
then an overall reduction in movements, similar to previous years. Fish released in
more downstream locations (>20km downstream of Revelstoke) exhibited less
movement. This suggested an active selection for deeper, lower velocity habitat that
was available in these areas. Operations of Revelstoke Dam and Arrow Reservoir
appear to have little effect on juvenile white sturgeon in the middle Columbia River,
since use of the riverine portion of the study area is limited. In 2009, substantially
higher use of more downstream areas was recorded, especially in the Beaton Flats
area. This was attributed to the different release locations used in 2009. The
strongest effect on juvenile sturgeon movement is the onset of darkness. The main
rearing habitats used were downstream of the riverine section within the direct
influence of Arrow Reservoir. This suggests that proposed flow treatments will not
likely produce discernable benefits for juvenile white sturgeon.

The information obtained to date from this monitoring program has provided insight
into the general locations of juvenile white sturgeon habitats and further effort will be
made in the coming years to better define the physical and hydraulic properties of
these habitats, their quantity and quality, the effect of Revelstoke Dam and Arrow
operations on these habitats, and whether operations can be modified to protect or
enhance these habitats. Finally, modifications will be required to the juvenile capture
portion to develop empirical estimates of growth and survival.

4.4 CLBMON-23 Mid Columbia River Sturgeon Egg Mat Monitoring & Underwater
Videography Feasibility Study

4.4.1 Overview

Annual sturgeon spawn monitoring below Revelstoke Dam is required to document
spawning events, timing, frequency, egg deposition, and habitat conditions. Due to
the low numbers of aging sturgeon in Arrow 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. Currently (as of 2008), there are no active transmitters
remaining in any adult white sturgeon in the Arrow Reservoir precluding this method
as a means of identifying spawning related movements until additional adults can be
tagged. As an alternative, the feasibility of using underwater videography (or
potentially other remote sensing methods) is being examined as a less-intrusive
means to assess staging of spawners and record actual spawning events to detect
presence of adults in the spawning area. 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.

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?

4.4.2 Status

The third year of the egg mat monitoring program was conducted in July and August of 2009 under contract to Golder Associates Ltd. (Castlegar). The final report for year 3 is appended to this report.

The third year of the underwater videography feasibility study was conducted in July and August of 2009 under contract to LGL Limited. The final report for year 3 is appended to this report.

In 2010, only the egg mat monitoring program will continue until the interim review of the Columbia WUP. Discussions with the white sturgeon Technical Working Group (April 2010) resulted in a decision to hold off on the use of videography as this technology has been sufficiently proven as a tool to determine presence/absence over the first three years of the program. The TWG recommended that direct measurements of spawning success (i.e. egg and larval captures) was important to continue in the Mid Columbia River until discussions around targeted flow releases will occur during the interim review.

4.4.3 Interpretation of Data

Egg Mat Monitoring Program – CLBMON 23a

Year 1 (2007) -- Thirty egg collection mats were deployed along 10 transects in the mid Columbia River from Revelstoke Dam to the Big Eddy over the period 25 July to 5 September, totalling 25 818 mat hours of effort. In addition, two D-ring drift nets were deployed; one upstream and one downstream of the Big Eddy for collection of white sturgeon larvae. No spawning event was detected in 2007 either through egg mat monitoring or larvae collection.

Year 2 (2008) -- White sturgeon spawn monitoring was conducted below Revelstoke Dam weekly from 17 July to 29 August 2008. Egg collection mats (29 stations) and D-ring drift net sampling were used to monitor white sturgeon spawning. In total, eight white sturgeon eggs were collected. Developmental staging of eggs and back-
calculation to estimate spawn timing indicated that two spawning events had occurred (31 July and 21 August 2008). The 21 August spawning event coincides with later spawning events detected in past studies, and represents the latest known timing of spawning throughout the species range.

Year 3 (2009) -- White sturgeon spawn monitoring was conducted below Revelstoke Dam from 15 July to 27 August 2009. Egg collection mats (20 stations) and D-ring drift nets were used to collect white sturgeon eggs and free embryos. In total, 65 white sturgeon eggs and 18 free embryos were collected. Developmental staging of eggs and backcalculation to estimate spawn timing indicated spawning occurred on the 3rd, 8th, and 18th of August 2009. These three events increased the total number of spawning events detected in the study area since 1999 to 11 (3 in 1999, 2 in 2003, 1 in 2006, 2 in 2008, and 3 in 2009). Cold water (often less than 10°C) and variable flow and water temperature conditions continue to create uncertainty in the amount of time required by eggs to reach certain stages of development. Data collected under CLBMON27 (described below) will help alleviate concerns around staging uncertainty in future years.

White sturgeon egg stranding was confirmed in 2009 following a flow reduction from Revelstoke Dam. Surveys conducted in a portion of a large dewatered cobble/gravel bar situated downstream from the spawning area recovered seven eggs. Additional data are required to assess whether this stranding rate is applicable to the entire cobble bar or other adjacent areas of the dewatered river bed. Main egg deposition and incubation areas were similar to past years and egg collection mats and D-rings continue to be the most effective methods to monitor white sturgeon spawning.

To date, the low number of spawning events and the highly variable physical environment within the spawning area confound our ability to address management questions related to the effects of Revelstoke Dam and Arrow operations on egg and larval survival and whether modifications can be made to these operations to protect or enhance white sturgeon incubation habitat in the middle Columbia River. Further data will be collected in 2010.

Underwater Videography Feasibility Study – CLBMON 23a

Year 1 (2007) -- On 1 August, a fixed station DIDSON (Dual frequency Identification Sonar) unit began recording from a location near the putative white sturgeon spawning site in the mid Columbia River at Revelstoke. A DIDSON was chosen for this feasibility study as the technology best suited for detecting adult white sturgeon presence in the mid Columbia River. Several mobile survey techniques were also tested to evaluate the DIDSON’s ability to detect sturgeon in various habitat types (e.g., pool and eddy). From 1-30 August, 267 sturgeon observations were recorded from the fixed station DIDSON with 6 of the images showing two sturgeon. None of the sonic tagged adult sturgeon in Arrow Reservoir was detected in the spawning area in 2007, therefore, these DIDSON detections are from other adults. The majority of detections occurred between 1 and 4 August, corresponding with recorded movement data and spawning events from other years (although no spawning event was detected in 2007).

Year 2 (2008) -- A fixed-station DIDSON system was deployed on the east river bank adjacent to the Revelstoke Golf Course and immediately upstream of the rip rap section of the river where the majority of white sturgeon embryos were captured in
1999 and where all embryos were captured in 2003 and in 2006. Fixed-station data were collected from 11 July to 27 August 2008. Line sampling, which involved manoeuvring the boat along a rope tied to the bow of the boat and fastened to an object on the bank, was also used extensively in 2008. A total of 64 observations of sturgeon were noted from the fixed DIDSON station in 2008; the first observation occurred on 13 July and the last on 23 August. There was one instance of two sturgeon observed simultaneously near one another in 2008. The majority of sturgeon movements in 2008 occurred from 1 to 3 August, immediately following a sturgeon spawning event estimated to have occurred on 31 July. Sturgeon activity within the sample area increased during nighttime hours relative to daytime hours in both years. Peaks in sturgeon activity occurred during the early morning hours in 2008. Mobile sampling did not detect any sturgeon in 2008. The results from the DIDSON fixed-station sampling demonstrated the feasibility of this technology for assessing movement of white sturgeon in Arrow Reservoir. Observational data provide information on patterns of general sturgeon behaviour that contributes to the knowledge base of the Arrow subpopulation.

Year 3 (2009) -- The feasibility of using DIDSON for monitoring white sturgeon presence and behaviour near a spawning area on the Columbia River below Revelstoke Dam was tested for a final year in 2009. The primary objective of this study was to assess the efficacy of DIDSON for monitoring the presence and behaviour of white sturgeon spawners. A fixed-station DIDSON system was deployed on the east river bank adjacent to the Revelstoke Golf Course and immediately upstream of the section of river where the majority of white sturgeon embryos have been captured to date. Sturgeon movement data from the fixed-station were collected at this site from 1 to 30 August 2007, 11 July to 27 August 2008, and 14 July to 25 August 2009. A second fixed-station site was established in 2009 about 1.6 km upstream from the golf course site to determine the upper extent of movement within this reach of river.

In 2009, 210 sturgeon observations were observed with peak activity occurring between July 28th and July 31st. Eleven instances occurred when more than one sturgeon was captured in the field of view at the same time in 2009. Sturgeon activity within the sample area generally increased during night-time hours relative to daytime hours in all years. Hourly peaks in sturgeon observations occurred during the early evening in 2009. The results from the DIDSON fixed-station sampling demonstrated the feasibility of this technology for assessing upstream and downstream movement patterns of white sturgeon in Arrow Reservoir. Observational data provide information on patterns of general sturgeon behaviour that contributes to the knowledge base of the Arrow subpopulation.

4.5 CLBMON-24 Mid Columbia River Sturgeon Genetics

4.5.1 Overview

Continuation of ongoing genetic assessment work to determine levels of stock differentiation in Arrow Reservoir and lower Columbia River white sturgeon is required as a pre-requisite to large-scale fish culture operations targeting release to the Arrow Reservoir. An additional year of related lab work is likely to be required to finalize direction on the need to address Arrow sturgeon separately.

The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) has been undertaking the analysis of genetic population structure of the Columbia sturgeon
populations since 2003, and completed nuclear DNA analyses on the samples in 2007. It is anticipated that this work will provide additional information to direct future work that may be required under the Columbia River Water Use Plan.

4.5.2 Status

In a letter dated 10 November 2008, BC Hydro requested that the deadline for submission of this Terms of Reference be delayed until year 9 (2015-2016) when results of nuclear DNA analyses could provide information to direct future work under the Columbia River Water Use Plan. Additional analyses are being undertaken on the suite of available samples collected from Columbia sturgeon, and it is expected that these results will not be available until late 2009. Furthermore, this timeline allows for the collection of additional genetic samples from various white sturgeon life history stages. Until the need for future work can be better defined, it is advisable that BC Hydro wait on preparing the Terms of Reference.

4.5.3 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.

4.6 CLBMON-25 Kinbasket Juvenile Sturgeon Detection and Habitat Use

4.6.1 Overview

This monitoring program will involve annual surveys and telemetric assessment of patterns of habitat use by juvenile sturgeon in Kinbasket Reservoir to address uncertainty as to whether habitats are sufficient to allow recruitment of larvae to age 1+ fish.

4.6.2 Status

This monitoring program is presently on the Conditional List, Clause 10.b., as its implementation is contingent on whether the decision is made to shift aquaculture efforts to Kinbasket Reservoir and the upper Columbia River in future years of the Columbia River WUP.

4.6.3 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.

4.7 CLBMON-26 Kinbasket Sturgeon Recolonization Risk Assessment and Habitat Suitability

4.7.1 Overview

This study is intended to provide the necessary information for assessing the feasibility of using the upper Columbia River and Kinbasket Reservoir to establish a recovery/failsafe area for white sturgeon. The basic approach of this project is to determine if the habitat in the upper Columbia River can provide conditions that support each of the sturgeon’s life stages. The project will survey potential spawning habitats to evaluate if they meet the required parameters, and if so, whether there are suitable habitats for free embryo, larvae and juveniles available in near proximity
to spawning areas to meet the early life stage requirements. Should it be determined that these suitable habitat is present, it is necessary to ensure ecological risk factors related to the release of hatchery produced juveniles are addressed, and that a conservation aquaculture program is developed to provide the necessary numbers of suitable life stages to provide the highest probability of establishing a population in the upper Columbia River.

The fundamental management questions to be addressed by the program are:

1. What are the ecological risks associated with the introduction of hatchery produced juvenile sturgeon into the study area, and have they been or could they be adequately addressed?

2. Are there suitable spawning habitats, free embryo hiding habitats, larval habitats and under-yearling and older juvenile foraging shelter-sites available in relatively contiguous circumstances within the study area?

3. What is the most applicable conservation aquaculture approach to establishing a sturgeon recovery or failsafe population in the study area?

4.7.2 Status

This monitoring program was delayed in 2009 for one year to be better informed following a second year of data collection from CLBMON-19. This monitoring program will be carried out over three years (2010 - 2012). A contract was awarded to Westslope Fisheries in partnership with CCRIFC. The work is scheduled to start in June of 2010.

Prior to conducting detailed habitat surveys, an ecological risk assessment will be developed using information from CLBMON-19, a literature review, and interviews with members from the Upper Columbia River White Sturgeon Recovery Initiative (UCRWSRI) Technical Working Group (TWG), the Kootenai River White Sturgeon Recovery Team (KRWSRT) and other experts. A list of parameters and locations examined in the habitat surveys will be finalized in consultation with these members prior to initiation of fieldwork in 2011.

4.7.3 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.

4.8 CLBMON-27 Mid Columbia River Sturgeon Incubation and Rearing Study

4.8.1 Overview

At present, there are only limited data regarding direct temperature effects on white sturgeon recruitment in the mid Columbia population. White sturgeon have been demonstrated to spawn in two very distinct sections of the Columbia River in British Columbia, Canada, which are both located immediately downstream of hydropower facilities. The thermal regimes differ substantially between these two areas. The general approach of this study was to incubate and rear white sturgeon early life stages under two thermal regimes; one mimicking the current, cool water regime of the mid Columbia River downstream from Revelstoke Dam, and one mimicking a
warmer regime similar to conditions found on the lower Columbia River at the international border. The primary objectives of this monitoring program are to:

1) assess the water temperature profile in the REV forebay area and its relationship to the thermal trend in the mid Columbia spawning area,

2) assess whether post-hatch cultured white sturgeon larvae released downstream of Revelstoke Dam display drift behaviour and development/growth similar to that observed in warmer temperatures, more common to sturgeon spawning, and

3) assess the magnitude of effect of a thermal regime on white sturgeon development, growth and survival during early life stages.

The scope of the monitoring program is based on three related but independent components. Information from the studies is expected to contribute to the mid Columbia sturgeon management plan review scheduled for 2011, and in the long term may influence subsequent or concurrent evaluations of Revelstoke and Arrow Lakes Reservoir operations and possible physical works alternatives.

4.8.2 Status

This monitoring program will be carried out over three years (2009-2011). The contract for this work was awarded to the United States Geological Survey in May of 2009.

4.8.3 Interpretation of Data

Year 1 (2009) -- The laboratory studies conducted in 2009 were comprised of two thermal treatments. One treatment used a temperature regime similar to present-day conditions on the Columbia River downstream from Revelstoke Dam and one treatment used a temperature regime similar to the Columbia River near the international border. The thermal profiles implemented during the laboratory incubation and rearing treatments were created by first acquiring historic temperature data from Revelstoke Dam and from a temperature monitoring station at Birchbank, (near the international border) and averaging the daily temperatures across years. Temperature profiles to be run simultaneously in the laboratory were created by rounding the historic mean daily temperatures to the nearest whole number, manually smoothing them to eliminate minor one to two day deviations in temperature from the overall trend, and selecting the smoothed daily temperatures that followed the approximate date of initiation of spawning by white sturgeon from the two representative areas (June 23 for Birchbank, August 8 for Revelstoke).

2009 results suggest that thermal regimes during incubation influence rate of egg development and size at hatch with colder water temperatures negatively influencing development. Eggs incubated under the warm thermal regime (i.e. Waneta) hatched sooner than those incubated under the cool thermal regime (i.e. Revelstoke). Mean length of free embryos at hatch was significantly different between thermal regimes with free embryos from the cool thermal regime being larger at hatch. However, free embryos from the warm thermal regime had a significantly higher mean weight at hatch. Mortality between hatch and initiation of feeding was extremely high in both treatments and virtually all fish reared under the warm thermal regime died prior to initiation of feeding. Similar results have been found in other studies examining growth and survival of sturgeon reared under warm water temperatures.
approximating those used in this study. A proportion of the fish reared under the cool thermal regime did begin feeding; however, growth rates were extremely low as the onset of feeding corresponded with decreasing thermal regime temperatures. Chronic low levels of mortality resulted in few fish remaining when the growth trials were terminated at 154 days after egg fertilization. Results from starvation trials showed that the fish in the warm thermal regime exhausted their yolk reserves faster than fish in the cool thermal regime. The ability to resist starvation may be important in dispersal to downstream rearing areas.

At the planning stages of the experimental design, the temperature profile representing the Waneta spawning area was assumed to serve as a control for comparison to the cold thermal regime results due to successful reproduction (demonstrated through egg and larval captures) occurring in that area annually. However, poor survival and performance of progeny reared under this thermal regime indicate that the Waneta area may actually be at the upper temperature threshold. Further to results from this study, results from two other recent studies (Kappenman et al 2009; and S. McAdam personal communication 2010) indicate similar results with warmer water temperatures approaching or exceeding 20°C. To address this issue in 2010, we will replicate the experiment at the Kootenay Sturgeon Hatchery using their typical rearing temperature of 15°C. These data will serve as a comparison and as a control since egg, larval, and juvenile survival is high in the hatchery environment.


4.9 CLBMON-28 Lower Columbia River Adult Sturgeon Population Monitoring

4.9.1 Overview

The Lower Columbia River Adult Sturgeon Monitoring is a 12-year program to monitor changes in age structure, population estimates, and population demographics. Included is an intensive acoustic telemetry component over the next 10 years, that will provide information on general movements, habitat use and population interactions, and potentially the identification of new/alternate spawning locations in the lower Columbia River. The monitoring program will also provide periodic spawn monitoring to measure trends in the numbers of spawning events, population demographics and reproductive potential, and provide an annual broodstock contribution to the conservation aquaculture program.

The monitoring program is designed to address a number of information requirements related to the adult life stage, but it will also provide a long term data set that will provide: (i) input to the ongoing consideration of recruitment failure hypotheses and the evaluation of the effects of future management responses on spawning success; and (ii) information to guide broodstock collection and stocking targets related to future conservation aquaculture programs and related recovery research initiatives.

The primary objectives for this program will have been met when:

1) Adult sturgeon life history characteristics including size, growth, age structure, condition, and population characteristics including abundance, population
trajectory, mortality rates, genetic status and reproductive potential are described and quantified with sufficient consistency to understand trends.

2) Biological characteristics including spawn monitoring to assess timing, success and general trends; and movements to assess seasonal habitat use and spawning site selection under the current range of operating conditions are defined.

A quantitative baseline of adult information needs identified in items 1) and 2) above has been established and maintained for the program period (2008-2019).

4.9.2 Status

This monitoring program will be carried out over 12 years (2008-2019). Initially, field work was conducted through a contract that was direct awarded to the Okanagan Nation Alliance and Golder and Associates. Since April 2009, BC Hydro has developed an alternative delivery program for this work and will be conducting this work (along with CLBMON 29 & 30) with an internal team. This delivery method ensures a high level of continuity, cost efficiencies, and an increased flexibility in program design that allows for adaptive change in response to new information. This adaptive approach is critically important for relatively under-studied species such as white sturgeon, but is difficult to provide using the typical consultant delivery model.

4.9.3 Interpretation of Data

Year 2 (2009) – Again in June and July 2009, white sturgeon spawn monitoring was conducted in the Columbia and Pend d’Oreille confluence area (the Waneta area). Spawn monitoring was conducted using the same protocol as in 2008 and was completed by Golder & Associates through a contract initiated and financially sponsored by Columbia Power Corporation (CPC) as part regulatory requirements of the Waneta Expansion Project. BC Hydro contributed to the delivery of the project by providing additional funding for increased sampling effort; and, BC Hydro, through a data agreement with CPC, retained all the data and samples collected. In total, 1715 eggs and 2 free embryos were captured during 21964 mat-hours of egg collection mat sampling; and an additional 77 eggs and 39 larvae were captured during 90.08 hours of D-ring sampling. Furthermore, 400 eggs were incubated in stream using an in situ approach, of which 65.3% successfully hatched, indicating that environmental conditions in this section of river are conducive for successful egg incubation and hatch. Similar to previous years, spawning occurred during the descending limb of the Pend d’Oreille River hydrograph and commenced after mean daily water temperatures in that system exceeded 14°C. The developmental stage of approximately 22% (n = 379) of the total eggs captured during egg collection mat and D-ring sampling was determined. Based on the time of egg capture, developmental differences among eggs captured, and the presence of recently spawned eggs, it is estimated that 15 discrete spawning events occurred during the 2009 study. This was the second largest number of spawning events recorded since spawning studies were initiated in 1993.

An array consisting of remote acoustic telemetry receivers (n=23) in the lower Columbia River (Hugh L. Keenleyside Dam to the Canada – U.S. border) resulted in 3,903,726 acoustic detections in 2009. Over 70 sonic-tagged white sturgeon were detected in 2009. Of these fish, all were adult staged and tagged in the lower Columbia River between Hugh Keenleyside Dam and Grand Coulee Dam in Washington or were adult sturgeon broodstock that contributed to the conservation
The 2009 broodstock contribution for the conservation aquaculture program resulted in 10 females and 8 males being sent to the Kootenay Sturgeon Hatchery in Wardner, BC in June 2009. During the broodstock acquisition component of the monitoring program a total of 172 sturgeon were sampled. Of the 172 fish captured, 46 sturgeon were new fish (never previously handled), 103 were recaptures (previously marked or handled in past studies), and 23 were hatchery released juveniles resulting from the conservation aquaculture program. Approximately 75% of the broodstock collected actually contributed to families released in the lower Columbia River in April 2010. All broodstock were released back into the lower Columbia River (at their respective capture locations) shortly following spawning, and all post spawn adults were implanted with sonic tags.

Results from this study supplement existing data and will assist in answering key management uncertainties regarding how operations of HLK may affect white sturgeon in downstream areas. The need for additional research into white sturgeon egg developmental rates in relation to water temperature was identified as necessary step in order to obtain estimates of variance associated with egg development rates. The need for a more detailed analysis of the telemetry data set was also identified in 2008, and as such a more detailed analysis of individual data to determine new spawning locations, was conducted in 2009.

4.10 CLBMON-29 Lower Columbia River Juvenile Sturgeon Monitoring

4.10.1 Overview

The lower Columbia River Juvenile Sturgeon Detection program is designed to describe life history aspects of juvenile white sturgeon, as well as provide input to the ongoing consideration of recruitment failure hypotheses, the evaluation of the effects of future management responses, and information to guide conservation culture stocking targets. The primary objectives of the juvenile sturgeon detection program are to:

1. Assess the development and condition (early hiding/drift development patterns and rearing juvenile conditions), behaviour (drift and movements), growth and survival of free embryo and juvenile sturgeon.

2. Determine early life stage distributions over time, locate free embryo hiding and juvenile rearing habitats, and define the parameters of these habitats.

3. Relate free embryo and juvenile habitat quality to variations in discharge from upstream dams and water levels of Lake Roosevelt reservoir.

4. Collect data in support of assessing the effects of current operations and the feasibility of management responses.

The scope of the juvenile program focuses on the collection of data that define free embryo and juvenile habitat conditions, the use of these data to determine the effect
of existing hydraulic conditions, and to identify and assess the most suitable of several management responses to be considered in lieu of operational changes.

To date, the UCWSRI has tagged, released and tracked sub-yearling conservation culture sturgeon within the lower Columbia reach for a number of years, and is aware of the location of their rearing habitat in Canada and the US. These habitats will continue to be used to monitor growth and survival among juveniles. Under this program, more consistent effort will be directed to assuring the accuracy of survival estimates by life stage and to defining the water quality, hydraulic, and substrate parameters of these habitats.

4.10.2 Status

This monitoring program will be carried out over 12 years (2008-2019). BC Hydro has developed an alternative delivery program for this work and will be conducting this work (along with CLBMON 28 & 30) with an internal team. This delivery method ensures a high level of continuity, cost efficiencies, and an increased flexibility in program design that allows for adaptive change in response to new information. This adaptive approach is critically important for relatively under-studied species such as white sturgeon, but is difficult to provide using the typical consultant delivery model.

4.10.3 Interpretation of Data

Year 2 (2009) – We conducted drift net sampling to determine the relative abundance and distribution of white sturgeon free embryos in the lower Columbia River. Sampling was conducted at three different locations within the lower Columbia River in an attempt to identify if spawning had occurred above each distinct location. We chose three sampling locations based on prior information related to white sturgeon spawning. The first drift net sampling site was located at river kilometre 5.1 (Site 5.1), with river kilometres (rkm) measured moving downstream from Hugh Keenleyside Dam (HLK, 0 rkm) to the Canadian United States international border (56.5 rkm). This site was chosen based on two criteria. The first criteria was based on telemetry observations of female (maturity stage F4) and male white sturgeon (maturity stage M2) predicted to spawn in 2009 migrating to immediately downstream of HLK (0.1 rkm). These fish were both tagged with acoustic transmitters in the spring of 2009 under a different Columbia Water Use Plan program (CLBMON#30). The second sampling criteria for drift net site 5.1 was based on qualitative observations of suitable spawning substrates and flows in the tailrace of Arrow Lakes Generating Station. Suitable spawning substrates can be qualitatively defined as cobbles and boulders while suitable spawning flows are typically swift water moving faster than 1-2 ms\(^{-1}\). The second site drift net sampling site was located at rkm 18.2 (Site 18.2). This site was chosen based on the capture of a single larval sturgeon in each of 2007 and 2008. The third sampling location was located at rkm 56.0 (Site 56.0) occurring just below the confluence of the Columbia and the Pend d’Oreille Rivers. This area is the only location where spawning has been documented (through egg and free embryo captures) and represents an area where a long term spawn monitoring program has been conducted since 1993 (Golder 2009). Zero larval sturgeon were captured at site 5.1 despite 3163 hours of sampling effort. At site 18.2, a total of 5 one day post hatch larvae were collected demonstrating that spawning had occurred above that location for the third year in a row. At site 56.0, a total of 39 larval white sturgeon of varying ages were collected as part of the 15 discrete spawning events identified in CLBMON#30. In 2010, the drift net program
will focus on further identifying the spawning location above Kinnarid (18.2). Drift nets will also be placed downstream of the Canada US border to examine patterns in drift for fish from the Waneta spawning area.

An annual juvenile white sturgeon program was initiated in 2009 to describe important parameters related to growth, survival and distribution in the lower Columbia River. This program will continue annually until 2018. In order to ensure a spatially balanced sampling design, the lower Columbia River study area was stratified into 5 equal zones (11.2 km in length). Sampling effort was randomly distributed with equal probability within and across each of the zones. Juveniles were collected using gill nets, set lines, and angling. A total of 198 juvenile white sturgeon were captured over a 4 week program. One of these fish was of wild origin, the remainder were stocked from hatcheries in Canada and the United States.

Average annual growth rates were extremely high and ranged from 14 cm in fork length for younger fish (1-3) and 10 cm per year for older aged juveniles (4-8). Interestingly, average annual weight increases were smaller for younger fish (1-4) and larger for older ones (age 5-8), suggesting that growth in total length is more important in the early years than weight. This is likely to escape predation from gape limited predators. Due to low recaptures during the program (3), survival could not be estimated. In 2010, an additional week of sampling will be added to the program and data across years will be used to develop age-specific survival estimates.

Furthermore, in 2010, age 1 juveniles will be released from the hatchery with acoustic transmitters to help identify movements and habitat use in the lower Columbia River.

A habitat map for the entire lower Columbia River is being developed using remote sensing techniques. A sidescan sonar was mounted to the survey boat and the Columbia River is being surveyed along transects parallel to the current from a downstream to upstream location. Data collected include location, water depth, and substrate classification (expected to be fines, sand, gravel, cobble, boulders). Substrate classification using the side scan sonar was calibrated using an underwater video camera attached to a grid with scales for measuring substrate diameter. Collected data will be displayed visually allowing capture and movement data to be overlaid for all age classes of white sturgeon. This will help with interpretation when attempting to address management questions. Data analyses and mapping are still underway from 2009.

4.11 CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events

4.11.1 Overview

The WUP Consultative Committee considered an experimental treatment involving a flow target of 200,000 cfs at the Canada/US border for one month during the late June to late July period to reduce predation pressures on larval and juvenile sturgeon in the lower Columbia River. However, it became apparent that achieving this target would require a large shift in current operations of Arrow Lakes Reservoir to supplement flows in most years and could be very costly due to implications on spill downstream in high flow years. As a result, the Committee recommended the high flow option only on an opportunistic basis, as opposed to through an operational change, and undertaking an assessment in those years when it occurs naturally. Based on historical frequency of occurrence, it was estimated that these high flow events would occur naturally in 2 out of 10 years.
The primary objective of the opportunistic assessment is to gain a better understanding of the relationships between high flows and sturgeon egg, larval and juvenile survival. The program will include, but not be limited to a spawn detection program, water quality sampling (water temperature, TGP, turbidity), and monitoring of juvenile survival and growth. The study will expand on the monitoring efforts developed for both the Lower Columbia adult sturgeon and juvenile sturgeon.

4.11.2 Status

This monitoring program will be carried out over 11 years (2009-2019). Initially, it was proposed that this monitoring program will be carried out in two years over the term of the Columbia River WUP when flows at the Canada/US border are expected to reach or exceed 200,000 cfs. However, it was apparent that spreading the effort across all years would be more informative by providing data across a range of flows. Field work was initiated in May 2009. BC Hydro has developed an alternative delivery program for this work and will be conducting this work (along with CLBMON 28 & 29) with an internal team. This delivery method ensures a high level of continuity, cost efficiencies, and an increased flexibility in program design that allows for adaptive change in response to new information. This adaptive approach is critically important for relatively under-studied species such as white sturgeon, but is difficult to provide using the typical consultant delivery model.

4.11.3 Interpretation of Data

Historical freshet levels, as defined in this study as 200 kcfs at the international border on the lower Columbia River, were not reached in 2009. Freshet flows have only reached levels greater than 200 kcfs three times since 2001 and the duration these flows have been maintained above 200kcfs has been relatively short. The ability to accurately predict freshet flows will be impacted by several factors including, Columbia River Treaty Flows, Non-Treaty storage, reservoir inflow rates during freshet, and Arrow Lakes Reservoir discharge rates during freshet. The feasibility and relative effectiveness of alternative water management scenarios targeted at years of higher predicted inflows will be further refined in the coming years.

The main objective for the first year of this study was to deploy acoustic transmitters in adult male and female white sturgeon that were predicted to spawn within 1-3 years of tagging. We were successful in deploying the majority of the acoustic transmitters allocated for the first year. A number of tags were not deployed due to capturing a higher proportion of females that were mature and predicted to spawn in 2009. Fish predicted to spawn in the same year as tag application occurred were not tagged due to our inability to determine how flow patterns influenced spawning related movements. This is attributed to tag application occurring after freshet flows had already begun to rise. These long term tags serve as an important tool to monitor movements in relations to flows within and across the years of this study (2009-2018). We were not able to look at movements in 2009 due to a limited number of months at large (i.e. approximately 6) that do not incorporate spawning/freshet periods. Examining movements of these tagged adult fish in the coming years will help to address management questions surrounding alternative spawning locations that might be used opportunistically in years of higher sustained flows.

In 2010 it will be important to collect measures of turbidity (nephelometric NTU) throughout the lower Columbia River to determine the effect that flows and river
location have on turbidity. Low turbidity has been shown to negatively impact early life stage survival of white sturgeon (Gadomski and Parsley 2005) and was identified as a key hypothesis in the recruitment failure hypotheses review completed by the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) Technical Working Group (Gregory and Long 2008). In 2010, turbidity meters will be installed above and below the confluence of the Columbia and Kootenay Rivers as well as at Waneta Eddy near the Canada US international border.

4.12 CLBMON-54 Mid Columbia Effects of REV 5 Flow Changes on Incubation & Early Rearing Sturgeon

4.12.1 Overview

Based on recommendations of the Revelstoke 5 Core Committee, the WUP addendum includes the requirement to undertake a study to assess pre- and post-project flow changes on incubation and early rearing habitat conditions for sturgeon in the mid Columbia River.

This project is an extension of CLBMON #20, which is designed to describe mid Columbia River spawning habitat depth, velocity, turbulence, and substrate using a detailed 3D model. BC Hydro is adding additional turbines to the Revelstoke Dam. A fifth unit, for which the project acronym is REV5, will result in the maximum discharge from the dam increasing to approximately 2124 m$^3$/s, when all 5 units are operating at full capacity. The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) Technical Working Group (TWG) recommended assessment of the effect this increase in discharge may have on the spawning, incubation and early rearing habitat of sturgeon downstream of Revelstoke Dam. To account for this recommendation, the Comptroller of Water Rights ordered BC Hydro to “assess pre- and post-project flow changes in incubation and early rearing sturgeon habitat conditions”. Based on TWG information, the term “early rearing sturgeon habitat conditions” is seen to refer to that life stage where the free embryo or post-hatch larva hide in the substrate immediately downstream of a spawning and incubation area while undergoing further development prior to dispersing to feeding habitats. In order to assess the suitability of habitat in the area for free embryos or post hatch larvae, habitat suitability indices will need to be developed for this work to be completed. It was proposed that the Delphi technique be used to develop the indices.

The technique involves solicitation of opinions from a set of established white sturgeon experts. A defining characteristic of the method is anonymity between opinions, and written correspondence is the primary means by which information is gathered. This ensures that the opinions of individual experts are respected and there is less opportunity for a single opinion to influence the outcome unduly. This portion of the work will be led by BC Hydro.

The fundamental management questions to be addressed through this monitoring program are:

1) What are the depth, hydraulic properties (velocity/turbulence) and substrate conditions in the identified white sturgeon incubation and suspected early rearing habitat area(s) below Revelstoke Dam?

2) How do Revelstoke Dam (including the addition of unit 5) and Arrow Lakes Reservoir operations affect hydraulic conditions in this/these area(s)?
3) How do these hydraulic conditions relate to incubation and early rearing habitat suitability (quality and quantity) for white sturgeon?

4) Can proposed minimum flows and spawning flow modifications to the operations of Revelstoke Dam protect or enhance mid Columbia River white sturgeon incubation and early rearing habitat?

4.12.2 Status

This monitoring program will be carried out over 2 years (2010 and 2012) and will be packaged with CLBMON-20 for cost efficiencies due to similarities in program design. A contract was awarded to Golder Associates (Castlegar BC) partnering with ASL environmental in the spring of 2010. Hydraulic modelling will be conducted to develop a 3 dimensional model that will allow accurate prediction of water velocities and flows over the white sturgeon spawning grounds at different reservoir elevations and flows from Revelstoke Dam. Given the complexity of flow conditions in the spawning area (influenced by flow inputs from two large rivers, Columbia and Jordan, and also include a large eddy feature), development of this high resolution numerical 3D flow model will allow the assessment of the effects of flow changes on sturgeon spawning habitat. The 3D numerical model has been previously used with great success to address similar questions at the Waneta Spawning area in the lower Columbia River. The model has the degree of resolution necessary to identify fine-scale changes adjacent to near-bottom areas of the river bed, which are important habitats for white sturgeon spawning, egg incubation, and early rearing. Finally, the 3D model is also capable of computing sediment properties (suspended sediment concentrations, deposition and erosion). This model will be used to not only determine the substrate currently present in the area, but will also be used to determine the effect that increased flows have on the habitat. This model will be a valuable tool when considering the long-term nature of sturgeon research programs in the mid Columbia River as it will allow the assessment of present and potential future changes to river hydraulics.

The first field sampling program collecting hydraulic data will occur in early June when Arrow Lakes reservoir elevations are low enough to not result in backwatering over the spawning grounds. A second field sampling session will occur in Mid July when Arrow Lakes Reservoir is near full pool and is resulting in backwatering over the spawning grounds. At this time a detailed substrate map of the spawning area will be developed using underwater videography and substrate samples. A second field sampling session will occur in 2012 following the implementation of REV5 to determine the effects of the increased flows on the early life stage habitat in this area. The Delphi approach to determine habitat suitability indices for early rearing stages of white sturgeon will be initiated in the summer of 2010.

4.12.3 Interpretation of Data

At this time, there are no data to interpret for this monitoring program.
5 Summary of Columbia River WUP Physical Works - Columbia River White Sturgeon Management Plan

This section summarizes the status of the physical works being implemented under the Columbia River White Sturgeon Management Plan of the Columbia River Water Use Plan, as per the Order under the Water Act, dated January 26, 2007.

5.1 CLBWORKS-24 Mid Columbia Experimental Aquaculture

5.1.1 Overview

The Mid Columbia River White Sturgeon experimental aquaculture is a 4-year program to provide juveniles for release into the river to assess impacts of flow treatment on sturgeon survival, and impacts of Arrow operations on juvenile habitat availability and suitability and juvenile survival. If these fish survive, the release will also contribute to the rebuilding of the existing mid Columbia sub-population. The specific objectives of this program are:

1. The incubation, rearing and annual release of approximately 4,050 healthy sub-yearling juveniles (including 50 juveniles of a size adequate for sonic nano-tagging) (in 2008-2011), comprised of those families most likely adapted to the conditions found in the mid Columbia, to facilitate research into juvenile habitat use and survival.

2. The incubation, rearing and release (in 2008 and 2009) of approximately 500,000 healthy post-hatch but unfed larval sturgeon (with reliance on parentage genetic markers as tags) to research larval survival.

3. The incubation, rearing and release (in 2010 and 2011) of approximately 100,000 healthy fed larval sturgeon (with reliance on parentage genetic markers as tags) to further research larval survival.

4. The annual marking and tagging of all sub-yearling/yearling releases according to protocol, including scute removal to designate brood year, Passive Integrated Transponder (PIT) tagging, sonic nano-tagging and other tagging as may be required.

5. Annual participation in public awareness and educational activities including but not necessarily limited to release events, school events, public events, open houses workshops etc.

6. Provision of testing and pilot programs exploring techniques for improved efficiencies and an ability to provide for broader genetic diversity of released stock.

An additional objective of the program is the incubation, rearing and release of juveniles resulting from the collection and incubation/rearing of collections on >200 wild eggs per year. The expectation is that if more than 200 eggs are collected within a year during egg mat monitoring of sturgeon spawning below Revelstoke Dam, the eggs will be retained on site in incubation canisters and the resulting larvae released to the mid Columbia Reach.
5.1.2 Status

The Mid Columbia Sturgeon Experimental Aquaculture program was initiated in 2006 through funding from the Revelstoke Unit 5 Project. Larval releases under the WLR program occurred in July of 2009, with over 300,000 unfed larvae being released into the Mid Columbia River in July. A total of 8,000 9-month old juvenile white sturgeon were also released into the river in late April 2010. A further 50 juveniles were marked with sonic-transmitters and released into the river for use in CLBMON-21.

Ongoing culture activities are being provided by the Freshwater Fisheries Society of BC (FFSBC), as the only entity within the province that has the necessary expertise and facilities to provide government-sanctioned sturgeon culture facilities capable of the requirements of the breeding plan. The program is being delivered by the FFSBC through a 4-year Contribution Agreement with BC Hydro and the Columbia Basin Fish and Wildlife Compensation Program.

5.2 CLBWORKS-25 Mid Columbia Sturgeon Conservation Aquaculture

5.2.1 Overview

In the longer term, a conservation aquaculture program is required to support the Arrow sturgeon population until such a time that stock abundance/age structure and habitat conditions can support a self-sustaining population and address residual impacts from providing lower than optimal spawning, incubation and rearing flows. If flow and stage conditions required to support a self-sustaining (or hatchery-supplemented) population are not economically feasible, a decision may be made to direct all or part of the conservation aquaculture effort to Kinbasket Reservoir.

The specific objectives of the program are:

1. The incubation, rearing and annual release of healthy sub-yearling juveniles, or unfed or fed larvae in sufficient numbers and combinations to provide for studies and management plans for either the mid Columbia or Kinbasket reaches during 2012-2018.

2. The annual marking and tagging of all sub-yearling/yearling releases according to protocol, including scute removal to designate brood year, Passive Integrated Transponder (PIT) tagging, sonic nano-tagging and other tagging as may be required.

3. Annual participation in public awareness and educational activities including but not necessarily limited to release events, school events, public events, open houses workshops etc.

4. Provision of testing and pilot programs exploring techniques for improved efficiencies and an ability to provide for broader genetic diversity of released stock.

A detailed approach of the conservation aquaculture program will be developed following the review of the mid Columbia sturgeon plan scheduled for 2011. Modifications may include release targets, timing, fish sizes, and both release locations and locations of remote incubation and rearing facilities. The UCWSRI
TWG is expected to be a key advisory body during the review, and will assist the WLR sturgeon management program with decisions on the approach.

5.2.2 Status
The Mid Columbia River White Sturgeon Conservation Aquaculture program is a 6-year program (2012-2018), which will be delivered by the FFSBC.

5.3 CLBWORKS-26 Mid Columbia Sturgeon Upgrade Hatchery

5.3.1 Overview
Upgrades of the culture facilities at the Kootenay Sturgeon Culture Hatchery (KSCH) in Wardner are required to support the experimental and conservation sturgeon aquaculture programs in the mid Columbia River. This involves:

1. The construction and full service provision of a portable incubation facility capable of handling the production of 500,000 post-hatch larvae to be initially located at the KSCH and completed in time for use during the 2008 brood year.

2. Relocation and full service provision of the portable incubation facility to a remote location (e.g., Revelstoke), and construction and full service provision of portable rearing facilities capable of producing 100,000 fed larvae at the same remote location or at the KSCH and completion in time for use during the 2010 brood year.

5.3.2 Status
Construction of a portable incubation facility at KSCH was completed in 2008 and the second phase, a second portable facility, was completed in the fall of 2009. This construction project was undertaken by FFSBC to provide facilities for the production of 500,000 unfed Columbia White Sturgeon larvae to be released into the mid Columbia River in each of 2008 and 2009. An additional 100,000 fed larvae are to be released in 2010 and 2011. Existing Columbia Sturgeon Culture facilities could not support this additional production. The most effective solution was to construct a portable container just outside the north side of the existing building. The existing water heating boilers, heat exchangers, and temperature and emergency alarms were utilized to supply heated water for the new incubation container.

A construction report for the portable facility is appended to this report.

5.4 CLBWORKS-27 Lower Columbia Sturgeon Physical Works

5.4.1 Overview
Given the low frequency and high costs of achieving a 200 kcfs flow target at the Canada/US border, the Columbia WUP Consultative Committee recommended turbidity augmentation in the lower Columbia River as a physical works in lieu. This plan involves the delivery of bentonite (or other turbidity agents) into the river during low flow periods (i.e., when discharge at the border is below 90 kcfs), and when sturgeon larvae are known to be hatching and undergoing their downstream drift phase. This was based on the premise that sturgeon spawn every year regardless of
discharge, but larvae would be most vulnerable to predation when flows are low and clear.

A technical working group involving members of the UCWSRI has since been established to examine and prioritize key hypotheses for sturgeon recruitment failure in the lower Columbia River, and provide direction to the Columbia Water Licence Program for undertaking a feasibility study of various physical works options.

5.4.2 Status

This physical works project is presently on the Conditional List, Clause 10.a. as its implementation is contingent on the outcome of the feasibility study. The Terms of Reference for the feasibility study (CLBWORKS-28) are being finalized in the summer of 2009.

5.5 CLBWORKS-28 Lower Columbia River - Planning and Assessment of White Sturgeon Physical Works

5.5.1 Overview

The Columbia WUP Consultative Committee recognized that a review and consultation with the agencies will be required prior to initiation of any physical works project to address recruitment failure of white sturgeon in the lower Columbia River to ensure that regulatory and legal issues are fully considered. Further, feasibility assessments will be required to address impacts on other interests in the river. Once a feasibility option has been identified, monitoring the response of the sturgeon population will be critical to informing on the effectiveness of the action and ensuring that adopted changes do not result in a decline in the population.

5.5.2 Status

A contribution agreement has been drafted between BC Hydro and the BC Ministry of the Environment to conduct the first part of work under CLBWORKS#28. The basic approach of this project is to develop physical works that can be implemented as mitigative actions focused on recruitment failure for white sturgeon in the lower Columbia River. This work will follow a staged process with the overall approach to build upon the recruitment failure hypothesis review completed by the Upper Columbia White Sturgeon Technical Working Group and summarized in Gregory and Long (2008) as a basis for decisions on appropriate response measures that would drive the development of physical works. The first stage of the approach will entail reconstructing historic impact timelines using a historic recruitment analysis that will incorporate currently available biological (e.g., fish ages) and physical data (e.g., water temperature, turbidity, etc.). This approach will follow the guidelines outlined in Task 3. The historic recruitment analysis work will be used to guide an initial comparison and ranking process to identify recruitment failure hypotheses that were most likely responsible for historic declines or periodic pulses in recruitment prior to 1985. Following this initial ranking process, restorative physical works options potentially available for high ranking hypotheses will be identified, evaluated, and described in detail. This will include a secondary ranking process that will address high ranking hypotheses from the first stage in terms of their feasibility for mitigation. Finally, for recruitment failure hypothesis that are highly ranked based on the analytical and feasibility approaches, experimental designs will be developed for
response measures within each of these hypotheses. The final technical report for the second stage of this work (Tasks 4 and 5 below) will include recommendations on pilot physical works projects that could be undertaken in the lower Columbia River.

MoE will start working on the project in June of 2010. The ministry will conduct work focused in the following areas:

- Develop and integrate findings of reconstructed recruitment timelines with reconstructed impact timelines using currently available biological and physical data.
- Rank hypotheses for those most likely to be causes of recruitment failure using information from the historic recruitment analysis.

The outcomes from this first part of the work will feed a project that will develop physical works for the hypotheses ranked highly as possible causes of recruitment failure. An assessment will then be conducted looking at the feasibility of implementing these various physical works in the river. This second part of the project will begin in late 2010.

5.6 CLBWORKS-34 Lower Columbia River Sturgeon Conservation Aquaculture Program

5.6.1 Overview

The UCWSRI has been releasing marked and tagged sub-yearling juvenile sturgeon into the lower Columbia River below Hugh L. Keenleyside Dam since 2002, which has numbered over 80,000 juveniles to date (2010). These fish are produced by the FFSBC at the Wardner facility. In addition, approximately 12,000 juveniles have been released from US hatcheries into Lake Roosevelt.

Since the culture program started, it has relied on various forms of support. Initially funded by BC Hydro and the province’s Habitat Conservation Trust fund, funding was provided by a combination of resources including major contributions from BC Hydro and the Fish and Wildlife Compensation Program – Columbia Basin (FWCP), and a number of other supporters including grant foundations and other industrial sources. However, reliability of full funding was not assured. To provide for dependable financial resources for the maintenance of the culture program, the WUP CC recommended that adequate funds be provided under the Columbia WUP to maintain the existing conservation culture program to provide juveniles to the Columbia Reach between HLK and the US border.

Specific objectives of this program include:

1. The capture, transportation between the Columbia River and KSCH, care and breeding of mature adult sturgeon at targeted numbers of 10 females and 10 males to provide for an annual objective of 8 genetically distinct families or secondarily subfamilies. Adults are to be returned to the Columbia River upon completion of spawning.
2. The successful incubation and rearing of approximately equal numbers of healthy juveniles from each family or subfamily bred in a given year targeting an annual release in the fall of the brood year or subsequent spring of a total of 12,000 sub-yearling sturgeon to facilitate stock rebuilding and research needs.

3. The annual marking and tagging of all fish according to protocols, including scute removal to designate brood year, Passive Integrated Transponder (PIT) tagging, nanotag sonic tagging and other tagging as may be required of both broodstock adult and juvenile sturgeon.

4. Annual participation in public awareness and educational activities including but not necessarily limited to release events, school events, public events, open houses workshops etc.

5. Provision of testing and pilot programs exploring techniques for improved efficiencies and an ability to provide for broader genetic diversity of released stock.

5.6.2 Status
The 2009 brood capture was conducted between 2-13 June in the Lower Columbia River including the Waneta Eddy and Fort Sheppard Eddy areas. Nine female and nine male sturgeon were captured and transported in a trailer-mounted transport tank to the Kootenay Sturgeon Hatchery. Seven of the nine female sturgeon were each spawned with four different males. All adults were released alive back into the Lower Columbia River near their location of capture. Four thousand juvenile sturgeon were released into the lower Columbia river in April of 2009.

6 Columbia River White Sturgeon Management Plan - Monitoring Programs and Physical Works Costs
The following table summarizes the approved costs of the monitoring programs and physical works under the Columbia River White Sturgeon Management Plan of the Columbia River WUP, as well as the Actual Costs to 31 May 2008.
### Table 6-1: Columbia River Monitoring Programs and Physical Works Costs

<table>
<thead>
<tr>
<th>Monitoring Programs</th>
<th>Activity</th>
<th>Costs approved by CWR</th>
<th>Total Forecast (Life to Date Actuals and Forecast)</th>
<th>Variance Total to Approved</th>
<th>Explanation</th>
<th>Corrective Action</th>
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<tbody>
<tr>
<td>COLUMBIA RIVER WHITE STURGEON MANAGEMENT INCUBATION &amp; EARLY REARING STURGEON</td>
<td>CLBMON#54 MCR EFFECT OF FLOW CHANGES ON EXISTING TAGGED ADULTS</td>
<td>$1,761,966</td>
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<td>Variance due to reporting. May be required for reporting in 2009.</td>
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<td>CLBMON#30 LOW COL OPPORTUNISTIC CLBMON#29 LOW COL JUVENILE STURGEON</td>
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<td>CLBMON#23 MID COL STURGEON EGG SUBSTRATE</td>
<td>$3,483,799</td>
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<td>CLBMON#28 LOW COL ADULT STURGEON HABITAT</td>
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<td>CLBWORKS#24 MID COL STURGEON EXPERIMENTAL</td>
<td>$51,455</td>
<td>$50,033.68</td>
<td>$1,421</td>
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<tr>
<td></td>
<td>CLBWORKS#25 MID COL STURGEON</td>
<td>$56,570</td>
<td>$55,767.30</td>
<td>$803</td>
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<tr>
<td></td>
<td>CLBWORKS#26 MID COL STURGEON HABITAT</td>
<td>$1,348,552</td>
<td>$1,324,947.63</td>
<td>$23,604</td>
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<tr>
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<td>CLBWORKS#27 LOW COL BENTONITE ADDITION</td>
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<td>$1,559,094.26</td>
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<td>CLBWORKS#25 MID COL STURGEON</td>
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<td>CLBWORKS#27 LOW COL STURGEON INCUBATION &amp; REARING</td>
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<td></td>
<td>CLBWORKS#24 MID COL STURGEON EXPERIMENTAL</td>
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<td>$329,239.63</td>
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