Columbia River Project Water Use Plan

Columbia River White Sturgeon Management Plan Monitoring Program and Physical Works

Annual Report: 2011

Implementation Period: May 2010 to April 2011

- 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)
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 April 2011, as per the Columbia River Order under the Water Act, dated 26 January 2007. There are 12 monitoring programs and six physical works included within this Management Plan and are listed below:

- 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
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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>
<thead>
<tr>
<th>Monitoring Program TOR</th>
<th>Order Clause</th>
<th>Original ToR Submission</th>
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<td>17 April 2008</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 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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| CLBMON-24 Mid Columbia River Sturgeon Genetics | | | | | | | | | | | | | *
| CLBMON-25 Kinbasket Juvenile Sturgeon Detection and Habitat Use | | | | | | | | | | | | | C* |
| CLBMON-26 Kinbasket Sturgeon Recolonization Risk Assessment and Habitat Suitability | ✓ | ✓ | ✓ | | | | | | | | | | |
| CLBMON-27 Mid Columbia River Sturgeon Incubation and Rearing Study | ✓ | ✓ | ✓ | | | | | | | | | | |
| CLBMON-28 Lower Columbia River Adult Sturgeon Population Monitoring | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| CLBMON-29 Lower Columbia River Juvenile Sturgeon Monitoring | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| CLBMON-54 Mid Columbia Effects of REV5 Flow Changes on Incubation & Early Rearing Sturgeon | | | | | | | | | | | | | × |

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<td>CLBWORKS-34 Lower Columbia Sturgeon Aquaculture Program</td>
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Legend:  
■ = Program to be undertaken/initiated in identified year  
u/w = Project is underway  
✓ = Program completed for the year  
× = Program started, but encountered operational or hydrological delays  
C* = Program is on the conditional list  
● = 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 Management Questions

The key management questions addressed by this monitoring program are:

1) Are white sturgeon present in Kinbasket Reservoir?

2) If white sturgeon are present in Kinbasket Reservoir, is it a remnant population or is natural recruitment occurring?

3) If white sturgeon are present in Kinbasket Reservoir or within habitats of the Columbia River upstream of the reservoir, what are the habitat associations for this population?

4.1.2 Overview

The Kinbasket Sturgeon Inventory and Habitat Use study was a 3-year investigation into the status and habitat use of white sturgeon in Kinbasket Reservoir and the Columbia River upstream. The study was descriptive in nature, and included surveys at key locations in an effort 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 were 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 be used in a subsequent 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.

4.1.3 Status

This monitoring program is complete. It was originally initiated in June 2008 and was conducted over three consecutive years. The work was completed through a contract award to CCRIFC in association with the Okanagan Nation Alliance (ONA) and Westslope Fisheries. The final report for this monitoring program is complete and appended to this document.
4.1.4 Interpretation of Data

Sampling sessions were conducted seasonally in each year (2008-2010) in an attempt to capture adult or juvenile white sturgeon in Kinbasket Reservoir. Sampling was conducted in a spring session (May), a summer session (July), and a fall session (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. A total of 882 setlines were deployed for 188 342 hook hours. While several burbot and pikeeminnow were captured, sturgeon were not encountered during the three year study. Thus it appears unlikely that sturgeon currently occupy the study area (Management Question 1).

There is interest in evaluating Kinbasket Reservoir as a potential recovery area for Columbia River white sturgeon (i.e. CLBMON 26), which are listed as endangered under the Species at Risk Act (SARA). The term recovery refers to a population level that ensures the long-term persistence and viability of a naturally producing population. A significant amount of effort was spent assessing the habitats available within Kinbasket Reservoir. Based on these surveys, the best available spawning and larval rearing habitats appear to be in the upper Columbia River downstream of Nicholson (Management Question 3). During the typical sturgeon spawning season (July and August), substrates in lower tributary reaches within Kinbasket Reservoir were observed as becoming overlain with sediment during rising reservoir. Since sediment deposition is an important early life stage mortality factor for white sturgeon and tributary water temperatures were measured at or below the lowest temperatures reported for sturgeon spawning, the major tributary confluences of Kinbasket reservoir and their lower reaches appear unsuitable.

Results of habitat work in this study are important as the upper Columbia River region offers access to extensive lacustrine foraging habitat (Kinbasket Reservoir), an unregulated hydrograph and thermal regime, and suitable substrate. This is the only region with these features in the Columbia and will be important to note during further evaluations regarding the potential establishment of a self-sustaining population of white sturgeon. In the upper Columbia River, substrate from Redgrave upstream to Nicholson was cobble/boulder/gravel, velocities ranged from 0.13 to 1.67 m/s, temperatures in July/August from 12.0 to 18.0 °C, and depths from 7-12 m common (17 m max depth sampled). The high turbidity (40 NTU’s) measured in this reach may provide cover to both spawning adults and larvae. In unregulated rivers, white sturgeon spawn at depths of 1.5-5.0 meters and turbidity of 42 NTU’s compared to lower Columbia sturgeon which prefer greater depths of 4-12 meters at turbidity levels less than 10 NTU’s.

Young-of-the-year Columbia River sturgeon show a strong preference for sandy substrate and water depths of 9-57 m (mean 30 m); however, in the presence of suspended sediments, white sturgeon larvae are found in much shallower habitats (0.5-6.5 m depths). The river from Nicholson to Donald had extensive areas of light coloured sand and gravel substrates, depths of up to 15 m, and turbidity levels of
20-40 NTU’s. Upstream of Nicholson, the river was shallower (max depths 4-7 m), sand and silt substrates were darker in colour (brown), and turbidity was similar to impounded systems measuring 8-12 NTU’s. Since Columbia River sturgeon have a weak embryo dispersal, and late embryos and larvae are photopositive, preferring habitats with lighter substrates and high suspended sediments to avoid predation, the glacial fines in the lower reaches may prove beneficial during dispersal. The common light grey body colour in larvae across populations is believed to be an adaptation for predator avoidance in a species where larvae and juveniles do not use bottom cover. Thus, the most suitable succession of spawning, embryo and larval rearing habitats for Columbia River sturgeon appears to be in the lower reaches of the Columbia River, from Nicholson downstream to Redgrave.

Though it is unlikely that white sturgeon occupy Kinbasket Reservoir, this study provided important habitat information for subsequent monitoring programs under the Columbia Water Use plan. This subsequent study, CLBMON 26, is described in more detail below.

4.2 CLBMON-20 Mid Columbia River Spawning Habitat Assessment

4.2.1 Management Questions

The key management questions addressed by this monitoring program are:

1) What are the depth, hydraulic properties (velocity/turbulence) and substrate conditions in the known or identified white sturgeon spawning and incubation area(s) below Revelstoke Dam?

2) How do Revelstoke Dam and Arrow Lakes Reservoir operations affect hydraulic conditions in this/these area(s)?

3) How do these hydraulic conditions relate to spawning habitat suitability (quality and quantity) for white sturgeon?

4) Can modifications be made to operations of Revelstoke Dam and/or Arrow Lakes Reservoir to protect or enhance mid Columbia River white sturgeon spawning habitat?

4.2.2 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 two-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 two-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.

4.2.3 Status

The implementation of this two-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, data requirements, and analyses. 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.

4.2.4 Interpretation of Data

The first field sampling sessions were implemented in 2010 in each of June, August and October. During each sampling session, transects were run collecting water velocities and depths at three different flow targets from Revelstoke Dam. Flow targets focused on low (5-10 kcfs), intermediate (20-30 kcfs), and high (50-60 kcfs) discharge levels from Revelstoke Dam. The June session was completed with Arrow Lakes Reservoir elevations (ALR) below 437 m, when the sturgeon spawning area
was not backwatered. Velocity and bathymetric data were collected at 6, 20, and 36 kcfs discharge levels from Revelstoke Dam. Operational challenges did not permit sampling at high discharge levels approaching 55 kcfs. Sampling conducted during August when ALR was above 437 m and backwatering over the spawning area was met with operational constraints. Two units at Revelstoke Dam went down due to issues associated with the installation of Unit 5. Sampling was only conducted at the intermediate discharge level. In October of 2010, a third sampling session was conducted to run transects at high flows out of Revelstoke Dam. Data were successfully collected at a discharge of 54 kcfs. Other data pertaining to substrate parameters were collected and are discussed below under CLBMON 54, which is packaged with this study for implementation.

The 3D model was developed during the first year of implementation. Data collected this year were implemented into calibration and verification model runs. The model is still in early development but calibration runs have proved to be robust in predicting the various physical parameters. Further data collection incorporating different flow scenarios at high ALR levels will be important in 2011.

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

#### 4.3.1 Management Questions

The key management questions addressed by this monitoring program are:

1) Where are the habitat locations utilized by juvenile sturgeon in the mid Columbia?

2) What are the physical and hydraulic properties of this habitat that define its suitability as juvenile sturgeon habitat?

3) What is the quantity of available habitat meeting these conditions in the mid Columbia?

4) How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile white sturgeon in the mid Columbia?

5) What are the survival rates of juvenile white sturgeon in the Mid Columbia River?

6) Can modifications be made to the operations of Revelstoke Dam and/or Arrow Lakes Reservoir to protect or enhance juvenile white sturgeon habitat?

#### 4.3.2 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.

4.3.3 Status

The first year of this monitoring program was initiated in April 2007 under a two-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 two-year period. A two-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.

4.3.4 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 habitats 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 (<20 km 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 (>20 km 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.

Year 4 (2010-2011) The program objectives were to document the survival of released hatchery juvenile white sturgeon, identify rearing habitats, and examine the effects of dam and reservoir operations on this habitat. Since May 2007, 28 533 PIT tagged hatchery reared juvenile white sturgeon, including 200 implanted with sonic tags have been released into the MCR. A Vemco VR2W remote telemetry receiver array has been used to monitor the movements of these sonic-tagged fish. Difficulties in fish capture to date have provided limited information to address the management questions. The focus of the 2010 study was to collect data on juvenile white sturgeon condition, growth, and diet, and to monitor movements and identify habitats used following release.
Four hatchery released juvenile white sturgeon were captured in 2010, for a total of 10 fish captured since 2007. To date, 4 of the ten juveniles captured have been fish equipped with sonic tags at release. These fish were larger at release (up to 6 times larger) and grew faster compared to fish without sonic tags. This suggests that in the MCR, size at release may influence survival given the large proportion of captures of that largest fish at release. Consistent with 2009, sonic-tagged juvenile white sturgeon were released in groups of 10 at five different locations approximately 10 km apart. Comparatively, in 2007 and 2008, all sonic-tagged fish (n = 50 each year) were released at one upstream location. This was conducted in an attempt to better understand reservoir use. Analyses of release locations indicated minor differences in the movement parameters examined across all years. In all study years, juveniles released in more upstream riverine areas typically exhibited rapid downstream movement to lower velocity habitats in ALR, at which point there was an overall reduction in movements. Fish released in more downstream areas, within the influence of ALR, exhibited less downstream movement. This suggested a preference for deeper, lower velocity habitat. It also demonstrates the importance of tailoring fish release sites based on the biological need of the species. Based on these results, juvenile white sturgeon released from the conservation aquaculture program will be stocked at Shelter Bay in the coming years.

Habitats in areas used by juveniles typically had depths over 10 m with fine substrates and low water velocities (less than 0.5 m/s). In 2007 and 2008, sonic-tagged juveniles exhibited highest use of areas from Blanket Creek (RKm 203.5) upstream (67% of total tag days), whereas in 2009 and 2010, highest use was from the Akolkolex River (RKm 200) downstream (74% of total tag days). For the combined 2007 to 2010, the highest overall use was documented at the Beaton Flats area (RKm 180; 14%). Use of this area increased substantially from 2.7% of total tag days in 2007 and 2008 to 22.9% in 2009 and 2010. Analysis of movement data indicated that the month of the detection of an individual was important for the evaluation of release site effects. Initially, juvenile sturgeon released from all sites moved downstream. The tendency for fish to move upstream increased as the season progressed. The time spent on station (i.e., near a VR2W station) also increased as the season progressed into fall. Although most juvenile movements occurred at night, neither time of day (day/night) nor Revelstoke Dam discharge at the onset of these movements had a significant impact on their magnitude or direction, or the time spent on station. Operations of Revelstoke Dam appear to have little effect on juvenile white sturgeon habitat use because use of the riverine portion of the MCR is limited. As such, flow treatments from Revelstoke Dam are unlikely to produce discernable benefits for juvenile white sturgeon. Results of this study provide insight into the general habitats used by juvenile sturgeon in the MCR and will inform future studies determining how Revelstoke Dam and ALR operations may influence the availability or quality of these habitats.

Work conducted over the past four years has generally described habitat use but has inadequately addressed how juvenile white sturgeon use the reservoir as conditions change throughout the year. This lack of knowledge may adding to low capture efficiencies. In order to address reservoir use in the Arrow Lakes, the proposed 2011 monitoring will differ from past years, which focused on capture, monitoring large scale post-release movements, and habitat use of juvenile white sturgeon. A Vemco Positioning System (VPS) has been proposed to monitor fine scale movements of hatchery released juvenile white sturgeon in 2012. The purpose of proposed 2011
monitoring is to conduct range tests at two locations during three seasons (spring, summer, and fall) to provide data on seasonal detection ranges and the best location to set up the VPS. This type of a system has proved very valuable in Lake Roosevelt to address similar questions. Furthermore, it is also important to have these data in hand for the interim review which will occur this coming winter as they will help direct further work in this area.

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

4.4.1 Management Questions

The key management questions addressed by this monitoring program 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 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.

4.4.3 Status

From 2007-2009, an egg mat monitoring program was conducted annually in July and August under contract to Golder Associates Ltd. (Castlegar). Concurrently during the
In 2010, only the egg mat monitoring program was implemented 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.

4.4.4 Interpretation of Data

**CLBMON-23a Egg Mat Monitoring Program**

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 backcalculation 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 CLBMON-27 (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.

**Year 4 (2010)** The primary objectives of the middle Columbia River white sturgeon spawn monitoring study were to assess sturgeon egg incubation sites and their physical conditions, determine the risk of egg stranding, and provide input to recommendations for the water allocation schedule for white sturgeon spawning and incubation. The 2010 study represents the fourth year of an ongoing monitoring program, conducted as a component of the Columbia River Water Use Plan.

White sturgeon spawn monitoring was conducted below Revelstoke Dam from July 22 to September 9 2010. Egg collection mats (20 stations) and D-ring drift nets (3 stations) were deployed to collect white sturgeon eggs and free embryos. White sturgeon eggs or free embryos were not collected in 2010. Since 1999, spawn monitoring has been conducted in nine years and spawning activity was detected in five of these years. To date, 11 spawning events (3 in 1999, 2 in 2003, 1 in 2006, 2 in 2008, and 3 in 2009) have been estimated to occur in the Revelstoke spawning area.

The apparent absence of spawning activity in 2010 supports results from previous studies that indicate spawning does not occur every year, likely due to the small population size and the multi-year maturation cycle of female white sturgeon. The ability to address management questions related to the effects of Revelstoke Dam and ALR operations on white sturgeon egg, free embryo, 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 has been challenging. This is attributed to intermittent spawning, the low number of spawning events that are detected in years when spawning does occur, and the highly variable physical environment within the spawning area.

### 4.5 CLBMON-24 Mid Columbia River Sturgeon Genetics

#### 4.5.1 Management Questions

The key management question addressed by this monitoring program is:

1) To be determined during terms of reference development

#### 4.5.2 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.

4.5.3 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 lower Columbia sturgeon, and the outcome of these results will help feed work under this monitoring program. 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.

4.5.4 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 Management Questions

The key management question addressed by this monitoring program is:

1) To be determined during terms of reference development if conditional work is implemented

4.6.2 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.

4.6.3 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.

4.6.4 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 Management Questions

The key management questions addressed by this monitoring 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 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.

4.7.3 Status

This monitoring program was initially 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 implemented over three years (2010 - 2012). A contract was awarded to Westslope Fisheries in partnership with CCRIFC. The work was initiated in the summer 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.
4.7.4 Interpretation of Data

In 2011, we are proposing to seek to answer the following portion of this overall question: “Are there locations in the Upper Columbia River (upstream of Kinbasket reservoir) that are in reasonable proximity to potential spawning habitats that provide suitable water quality (temperature and turbidity) for egg survival and development? These data will help inform evaluations of different potential spawning area suitability.

The proposed study area is the only remaining portion of the Columbia River that is unregulated and is comprised of a natural hydrograph and sediment load. Sediment deposition in spawning areas has been indicated to be an important early life stage mortality factor for white sturgeon that is mitigated by temperature (i.e., cooler water temperatures lengthen the incubation period and therefore the duration of susceptibility to moving sediments by several days (Kock et al. 2006). Sturgeon egg survival in the turbid Kootenay River is low and is believed to result from spawning habitats (with underlying cobble substrates) having become overlain with fines (sand), possibly as a result of flow regulation (MacDonald et al 2010). This impact is further accentuated as the Kootenay River is significantly colder than the upper Columbia and eggs are exposed to greater amounts of fines over a protracted period. While the annual spawning location in the lower Columbia River near Waneta has a similar temperature profile, it lacks the higher turbidity level, which can reduce predation on early life stages. Thus, the proposed region for experimentation is unique in its combination of temperature, turbidity, and flow.

The enclosure experiment will be designed and replicated within and among different potential spawning locations within the Upper Columbia River (50 rkm from Golden downstream to Beavermouth) examining egg survival and development under a range of turbidity (10-40 NTU's) and flow conditions. Egg array sites will target habitat characteristics associated with the most successful remaining populations of white sturgeon, where natural recruitment still occurs with some regularity. Potential experimentation sites proposed are: Nicholson, Golden, Donald, Redgrave. The Nicholson and Golden sites offer finer substrates (gravel and sand) with turbidity in the mid range (20-25 NTU's) while the Donald and Redgrave sites offer courser substrates (cobble/boulder) with higher turbidity (25-40 NTU's). The work will be done during post peak conditions in the first week of July (6-7 July 2011. Note: due to the areas high elevation, peak flows at Donald occur from 25 June to 05 July and approach 800 cms. Velocities in the proposed experimentation sites range from 0.72 to 1.67 m/s and depths from 3 to 17m.

To minimize the risk of egg or larval loss from the enclosure experiment, white sturgeon eggs will be incubated using incubation trays. This specific tray design has been used successfully to incubate eggs in situ at the Waneta spawning area over the past several years. The incubation trays consist of a thick plexiglass sheet with 100 wells distributed in a rectangular grid pattern. The size of the wells is adequate enough for free embryos to hatch and survive until the entire system is retrieved. The design allows water to flow over the eggs from the top and bottom sides of the tray, allowing the eggs to remain oxygenated and helps prevent sediment from building up. Further, the design allows easy identification of dead or alive eggs over time as eggs are incubated individually. The incubation trays will be deployed in arrays of up to 6 per site. The four sites proposed are Nicholson, Golden, Donald, and Redgrave.
Two arrays will be anchored at each site. They will be weighted and deployed near the river bottom. Trays will be placed both on the bottom and suspended just off the bottom (0.5 m) to examine the effects of bed load and suspended sediment on survival. Water temperatures at the incubation array will be recorded at hourly intervals. The free embryos from eggs that successfully hatched will be preserved for morphological measurement. Work using these systems in the lower Columbia River to date suggests that the risk of egg loss from the trays into the river is extremely low. These arrays would be monitored daily during the experiment and cleaned if needed to ensure entire arrays are not lost into the river. Even if an array of incubators were lost, the probability of an incubation tray breaking open would be small given the physical size and small profile of the system.

This study is intended to provide some of 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 (substrate, velocity, depth, contaminants), as identified in the literature, 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.

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

#### 4.8.1 Management Questions

The key management questions addressed by this monitoring program are:

1. What is the relative success (as displayed by developmental condition, growth and survival) of early life stage white sturgeon reared in the laboratory under different temperature regimes, and what is the magnitude of the effect attributable to temperature?

2. Assuming that the early life stage success of white sturgeon is dependant on rearing temperature, what life stage is most affected (or constitutes a bottleneck)? For example, is it the hatching date, pre-winter growth, over-winter metabolic rates, or a combination of factors?

#### 4.8.2 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.

4.8.3 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.

4.8.4 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 2009¹; 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.

Year 2 (2010) – We completed the second year of a three-year investigation on the effects of different thermal regimes on incubation and rearing early life stages of white sturgeon. 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 Columbia River downstream from Revelstoke Dam, and one mimicking a warmer regime similar to conditions found on the Columbia River at the international border. Second-year results suggest that thermal regimes during incubation influence rate of egg development and size at hatch. Eggs incubated under the warm thermal regime hatched sooner than those incubated under the cool thermal regime. Mean length of free embryos at hatch was significantly different between thermal regimes with free embryos from the warm thermal regime being longer at hatch. However, free embryos from the cool thermal regime had a significantly higher mean weight at hatch. This is in contrast with results obtained during 2009. Laboratory data on overall growth and survival equating to the first rearing season showed that highest mortality occurs during the transition to exogenous feeding. Although fish reared in the warm thermal regime had higher mortality at the initiation of exogenous feeding, fish reared in the cool thermal regime exhibited higher chronic mortality throughout the rearing period, suggesting a reduced capacity for survival under prolonged rearing in cool water. Larger size at entry into a winter period has also been associated with greater survival in some fish species. In this laboratory study, fish reared under the cool thermal regime with a shortened first year growth period were quite small, with a

mean TL of 44 mm (range 28-62 mm). In contrast, fish reared under the warm thermal regime and longer first-year growth period were substantially larger with a mean TL of 147 mm (range 72-208 mm). For comparison, age-0 fish captured during fall bottom trawling from the Columbia River downstream from Bonneville Dam were at least 176 mm TL. In addition to growth and survival metrics, survival capacity was assessed via starvation experiments. Fish reared in the cool thermal regime survived longer in the absence of food, suggesting that they may be more able to survive a prolonged period of dispersal to productive foraging areas. Finally, lipid assessments that are underway will provide an additional assessment of fish condition transitioning into winter months.

The third and final year of this study will begin after the first spawning period at the Kootenay Trout Hatchery is complete.

4.9 CLBMON-28 Lower Columbia River Adult Sturgeon Population Monitoring

4.9.1 Management Questions

The key management questions addressed by this monitoring program are:

1) What are the abundance trends, population structure and reproductive status of adult white sturgeon in the lower Columbia River?

2) How much spawning occurs annually at known spawning locations, and are there other spawning locations unidentified in the lower Columbia River?

3) What is the degree of interaction among sub-populations of sturgeon in the lower Columbia River?

4) How do existing river operations affect adult movements, habitat preference, spawning site selection or spawning?

4.9.2 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).

4.9.3 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 and 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.

4.9.4 Interpretation of Data

White sturgeon spawn monitoring was conducted in the Columbia and Pend d’Oreille confluence area (the Waneta area) in June and July of 2010. Spawn monitoring was conducted following consistent sampling protocols that have been in place the past decade. In total, 4891 eggs and 16 free embryos were captured using egg collection mats, and an additional 888 eggs and 89 larvae were captured using passive sampling drift nets. The developmental stage of 15% \(n = 718\) of the total number of eggs collected was assessed to back predict time of fertilization and estimate the number of spawning events. Based on the time of egg capture and assigned developmental differences among eggs collected, it is estimated that a minimum of 27 spawning events occurred during the 2010 study. This is the largest number of spawning events estimated since spawning studies were initiated in 1993. Furthermore, 1000 eggs were incubated in stream using an \textit{in situ} approach, of which 49% successfully hatched. In previous years, spawning has 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. Comparatively in 2010, 37% \(n=10\) of the minimum estimated number of spawning events \(n=27\) occurred prior to the peak freshet date on June 21st and almost a week prior to the mean daily water temperatures in the Columbia river system reaching 14°C. While it is not considered uncommon for the species to spawn on both the ascending and descending limb of the hydrograph, it is considered rare in the lower Columbia River and in particular at the Waneta spawning site, as this has only occurred once in the past decade. Similar to 2009 results, both egg mats and drift nets were sampled in other areas of the lower Columbia River in an effort to identify alternate spawning locations. In 2010, an additional 43 eggs were captured upstream of the Waneta site;
42 were captured at the Arrow Lakes Generating Station tailrace and a single egg was captured at river kilometre 18.2. An additional 122 larval white sturgeon were caught in the upper section of the lower Columbia River using drift nets. 114 larvae of were captured in the ALGS tailrace area and 8 larvae were captured at sampling site 18.2. All of the 122 larvae captured were preserved for developmental staging, morphological measurements and future genetics analysis.

A permanent 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 3,944,472 acoustic detections in 2010. Over 100 active sonic-tagged white sturgeon were detected in 2010. Of these fish, most (n>75) were adult stage 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 aquaculture program in 2007, 2008, 2009 and 2010. The remaining 25 were juvenile sturgeon from the 2009 brood year that were released at various locations (5 locations within the 56km stretch of river between Hugh Keenleyside Dam and the Canada/U.S. International Border) in the lower Columbia River in May 2010. Based on telemetry data, habitat use remained consistent with previous years and areas of high use included HLK Eddy, Robson Reach, Kootenay Eddy, Fort Shepherd Eddy, and Waneta Eddy. Peak movements occurred during the summer months, however fish initiated movements on a monthly basis. Examinations of individual fish movements during the 2009 predicted spawning period revealed that two mature males implanted with acoustic transmitters in 2009 exhibited possible spawning related movement to the HLK Eddy area. It was unknown whether these two fish spawned but these movements triggered an investigation of alternate spawning location, and in July 2010, focused spawn monitoring efforts in the HLK Eddy area confirmed an additional spawning location in the tailwater of Arrow Lakes Generating Station.

The broodstock contribution for the conservation aquaculture program resulted in 10 females and 10 males being sent to the Kootenay Sturgeon Hatchery in Wardner, BC in June 2010. During the broodstock component of the monitoring program a total of 122 sturgeon were caught, assessed for previous tags, measured for weight and length, and assigned a maturation stage. Of the 162 fish captured, 36% (n=59) were new fish (never previously tagged), 83 were recaptures (previously marked), and 20 were hatchery released juveniles from the conservation aquaculture program. The majority of the adults collected during the broodstock program contributed to families released in the lower Columbia River in April 2011. All broodstock were implanted with sonic tags and released back into the lower Columbia River (at their respective capture locations) shortly following spawning.

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 variation associated with development to refine estimates of total numbers of annual spawning events. The need for a more detailed analysis of the telemetry data set was identified, and as such a more detailed analysis of individual data to determine new spawning locations, was conducted this year and is ongoing.
4.10 CLBMON-29 Lower Columbia River Juvenile Sturgeon Monitoring

4.10.1 Management Questions

The key management questions addressed by this monitoring program are:

1) What are the relative abundance, survival rates and distribution locations of free embryo and juvenile white sturgeon in the lower Columbia River under current operating parameters?

2) What are the physical and hydraulic properties of this habitat that define its suitability as juvenile sturgeon habitat?

3) How do normal river operations affect free embryo habitat conditions in the lower Columbia River?

4) How do normal river operations affect juvenile habitat conditions in the lower Columbia River during dispersal and on a seasonal basis?

4.10.2 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.

4.10.3 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 and 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.

4.10.4 Interpretation of Data

We conducted passive sampling using drift nets in order to determine the relative abundance and distribution of white sturgeon free embryos in the lower Columbia River. Consistent with previous years, sampling was conducted at multiple locations within the lower Columbia River in an attempt to identify if spawning had occurred above each distinct location. These locations were dispersed through the Canadian section and in the United States downstream of Waneta. We chose all sampling locations based on prior information related to white sturgeon spawning. The first drift net sampling site was located at HLK/ALGS where spawning was documented using egg mats. 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 and several in 2009. 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). Finally, we distributed 7 sites downstream of Waneta in the united states to look at downstream dispersal patterns. We collected over 100 post hatch free embryos at HLK/ALGS. All larvae captured were immediately post hatch (~ 1 day of age). Two spawning events were identified at this site based on larval captures. No larvae older than 1 day were collected suggesting that hiding habitat is lacking for that area. At site 18.2, a total of 10 one day post hatch larvae were collected demonstrating that spawning had occurred above that location for the fourth year in a row. The ages of larvae collected did not align with spawning events at HLK/ALGS suggesting that an alternate spawning location exists in the upper section of the lower Columbia River. At site 56.0, a total of 90 larval white sturgeon of varying ages were collected as part of more than 20 discrete spawning events identified in CLBMON-28. Downstream of Waneta dispersing larvae were collected at multiple sites, and are assumed to survive as far as Northport as peak collections by US biologists align with peaks in downstream dispersal event at Waneta. Many of the larval captures at Waneta were of young age suggesting that habitat for successful hiding might be limiting. In 2011, the drift net program will focus on further identifying the spawning location above Kinnarid, in the Kootenay, and downstream of HLK/ALGS. 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 continued in the fall of 2010. 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 three methods: gill nets, set lines, and angling. A total of 326 juvenile white sturgeon were captured over a 5 week program. Similar to 2009, one of these fish was of wild origin, and the remainder were stocked from hatcheries in Canada and the United States. The distribution of fish throughout the lower Columbia River was examined. High habitat use was documented in the Robson stretch, near Kinnaird, and downstream near Waneta. Generally, older ages represented larger proportions of the total catch (e.g. 25% 9 year olds) but all hatchery release ages were represented within the high use areas. Average annual growth rates were extremely high and remained consistent with those observed in 2009. Annual growth rates ranged from 14 cm in fork length for younger fish (1-3) and 10 cm per year for older aged juveniles (4-8). 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. A weight length relationship was developed and can be used to assign age from weight for wild fish. Low recaptures during the program precluded estimating age specific survival. In 2010 25 juveniles were released from the hatchery with acoustic transmitters. They were tracked using the current array to determine post release movements and help identity habitat use. Results from these acoustic tagged fish were similar to results from CLBMON 21 in the MCR. Fish exhibited large downstream movements (regardless of their release location) within 24 hours of being released. 12% (n=3) of the juveniles were never detected on the array following release while 32% (n=8) of the juveniles selected habitats in the United States portion of the Columbia River between the Canada/U.S. International Border and Grand Coulee Dam. The remaining juveniles were distributed among high use habitats preferred by lower Columbia River white sturgeon. Finally, in 2011 the program will target areas of high use to increase the total number of recaptures available for survival analysis. This will be done by using distribution data from the first two years of the program. We will retain the spatial random sampling program but limit the sampling to demonstrated high use areas.

A detailed habitat map for the entire lower Columbia River is being developed using side scan sonar. 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 was assigned using Quester Tangents QTC Sideview. Calibration of substrate classification results was conducted using an underwater video camera attached to a grid with scales for measuring substrate diameter. Data processing and calibration is ongoing. Finished habitat maps will be used to display data visually from a number of WUP programs in the lower Columbia. It will also allow sturgeon capture and movement data to be overlaid for all age classes. This will help with interpretation when attempting to address management questions.
4.11 CLBMON-30 Lower Columbia River Opportunistic Assessment of High Flow Events

4.11.1 Management Questions

The key management questions addressed by this monitoring program are:

1) Are there unidentified spawning sites in the lower Columbia River that are used during higher flows?

2) How does the interaction among presumed subpopulations of sturgeon in the lower Columbia River change during high flow events?

3) Are probabilities of survival higher at the egg stage in years of higher flows?

4) What effects do higher flows have on recruitment to the larval stage?

5) What is the effect (and associated mechanisms) of higher flows on juvenile survival in the lower Columbia River?

4.11.2 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.

4.11.3 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. This original plan would have resulted in increased effort in only years where flows were forecasted to surpass the 200,000 cfs level. However, it was apparent during the development of the ToR that spreading the effort across all years would be more informative by providing data across a range of flows. Field work for this program 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 and 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.

4.11.4 Interpretation of Data

Water management on the Canadian portion of the Columbia River for flood control and power generation has significantly altered the hydrograph in relation to historical patterns. It has been suggested that changes in historical freshet patterns has the potential to affect conditions necessary for recruitment, including changes to physical habitat, temperature regimes, and turbidity levels. Historical freshet levels, as defined in this study as 200 kcfs at the international border on the lower Columbia River, were not reached in either 2009 or 2010. Freshet flows have only reached levels greater than 200 kcfs on three occasions since 2001 and the duration these flows have been maintained above 200 kcfs has been relatively short (range 9-17 days). Another year of attempting to predict freshet flows demonstrated that inflow forecasts cannot be used reliably to determine water levels in enough lead time to coordinate additional sampling programs or contingency plans. The ability to predict freshet levels and dictate sampling effort or water resources is further 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 is complicated. Consistent sampling across years and associated flows will provide a more reliable method of determining the effect of high flows on recruitment.

A study objective was to deploy acoustic transmitters in adult male and female white sturgeon that were predicted to spawn within 1-3 years of tagging. These transmitters were successfully deployed and tracking data was collected throughout the following 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. Tracking data from these fish does not reveal distinct movements in relation to changing flows. Movements assumed to be spawning related were identified but were not qualitatively different from previous years. Habitat use was high in areas that were consistent with past years, these include the entire Robson stretch, Kootenay Eddy, and the lower part of the study area (e.g., Fort Sheppard and Waneta). Long term tracking data will serve as an important tool to monitor movements in relations to flows within and across the years of this study (2009-2018). Using these data to examine movement of tagged adults 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. Further tracking data from tagged juveniles (wild or hatchery origin) may also provide information on how these fish use the lower Columbia River and if areas of use change in years of higher flows.
Examining the timing of spawning in relation to peak freshet flows demonstrates that sturgeon spawn primarily on the descending limb of the hydrograph (data from 2000 to current). This result is important as it suggests that while the overall magnitude of the flows are important, the shape of the hydrograph is like a critical cue along with temperature for spawning. Spawning was documented at several locations in 2010 due to expanded efforts in other sections of the river. In addition to Waneta and Northport, spawning was documented at another location in the US, is assumed to have occurred above Kinnaird, and was documented at HLK/ALGS. The documentation of spawning at HLK/ALGS is new but flow related effects resulting in fish spawning at this location are not evident. Further monitoring at this location will be required over the coming years.

Moving forward it will be critical to document 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 (see 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 were installed above and below the confluence of the Columbia and Kootenay Rivers as well as at Waneta Eddy near the Canada US international border. Logistical challenges in keeping equipment in place in the river precluded consistent turbidity monitoring. Further refinements are planned for 2011.

Importantly, recruitment pulses originating from years of high flow might be best identified through annual juvenile monitoring. Monitoring spawning activity will be important moving forward but efforts to date to correlate recruitment to the egg or larval stage with annual flows have not been successful. Finally, at the time of this annual report preparation, flows have exceeded the 200 kcfs threshold at the international border and are predicted to approach levels greater than 225 kcfs. Therefore, data collected in 2011 will be important for future analyses.

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

4.12.1 Management Questions

The key management questions addressed by 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 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.

4.12.3 Status

This monitoring program will be carried out over 2 years (2010 and 2012) and was packaged with CLBMON-20 for cost efficiencies and implementation 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 the physical substrate over the 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 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.

Interpretation of Data

In addition to the velocity and bathymetric data collected and described under
CLBMON-20, this project also collected substrate data throughout the study area.
Substrate surveys were conducted in 2010 using an underwater camera. A scale bar
was included to enable size determination of the substrate observed. Still photos
were extracted from selected locations within each transect. Further, substrate was
physically collected from several areas and sieve analysis will be conducted to
determine sediment properties. Sieve analysis will contribute to bottom roughness
coefficients for use in the 3D model. Analysis of photos collected from the video
transects is underway and will be complete in 2011. Current results suggest high
embeddedness and armouring of the substrate.

Following model development and verification, a detailed substrate map of the area
pre-REV5 flows will be produced. Two years following the initiation of REV5, a
subsequent sampling period will be conducted to determine if the additional flows
from REV5 have resulted in a change to substrate important for early life stages of
white sturgeon.

The Delphi approach to determine habitat suitability indices for early rearing stages
of white sturgeon will be initiated in the fall or winter of 2011/2012.

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 August of 2010, with over 100,000 fed larvae being released into the Mid Columbia River. 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 Kinbaskert 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 Kinbaskert 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.

5.4 CLBWORKS-27 Lower Columbia Sturgeon Physical Works

5.4.1 Overview

Given the low frequency and high costs of achieving a 200 kcf/s 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 kcf/s), 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. CLBWORKS-28 is currently underway and results will inform designs around this physical works program.

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 was signed 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 has focused on 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.). The specific objectives of this work are to: 1) estimate the timing and magnitude of recruitment decline; 2) evaluate the effect of ageing error and imprecision on recruitment trends; 3) evaluate whether trends in recruitment are different between different groups of sturgeon within the lower Columbia River; and 4) relate estimated recruitment trends to independent variables (e.g., environmental variables) to attribute cause for declines overall or by specific groups. 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 will include recommendations on pilot physical works projects that could be undertaken in the lower Columbia River.

MoE started working on the first phase of the project in June of 2010. A final draft of the report is complete and is currently in review by two independent reviewers and members of the technical working group. Following completion of this report, the second phase will be contracted out and the feasibility of physical works study initiated.

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 2010 brood capture was conducted in early June in the Lower Columbia River including the upper sections of the river, Waneta Eddy and Fort Sheppard Eddy areas. Ten female and ten male sturgeon were captured and transported in a trailer-mounted transport tank to the Kootenay Sturgeon Hatchery. Eight of the ten female sturgeon were successfully spawned. Spawning took place on June 23 and July 7, 2010. 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 2010. Juvenile white sturgeon were dispersed at the time of stocking in the lower Columbia River. Groups of fish were released at HLK, Kootenay Eddy, Genelle, Trail, and Beaver Creek. These releases were based on observations of habitat use under CLBMON 29.

6 Mid Columbia White Sturgeon Management Plan Interim Review

The interim review for the mid Columbia white sturgeon program is planned for this coming year. The review will focus on addressing questions outlined during the consultative committee process. It was decided to wait until completion of the field season in 2011 to initiate the review. Following the field season there will be more reliable data available to address questions during the review where uncertainty remains. This will include a more finalized hydraulic model to assess flow treatments, information pertaining to juvenile monitoring, and further progress related to the ecological risk assessment being prepared for Kinbasket. The current review committee consists of First Nations, Agency, Industry, and Stakeholder representation. A formal update on the review will be available following the conclusion of the process in early 2012.

7 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 30 April 2011.
## Table 7-1: Columbia River Monitoring Programs and Physical Works Costs

<table>
<thead>
<tr>
<th>Monitoring Programs</th>
<th>Activity</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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<tr>
<td>COLUMBIA RIVER WHITE STURGEON MANAGEMENT PLAN Annual Report</td>
<td>Non-remissible</td>
<td>14,596</td>
<td>1,274.25</td>
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<td>None required at this point</td>
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<td>Budget to be reassessed based on outcomes of 2011 field results.</td>
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<td>Implementation</td>
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<td>COLUMBIA MED COL JUVENILE STURGEON DETECTION &amp; HABITAT USE STUDY &amp; TRACKING OF EXISTING TAGGED ADULTS</td>
<td>Direct Management</td>
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<td>1,360,345</td>
<td>114,107.03</td>
<td>Efficiencies found in project delivery to date, but may not be utilized in future years following MCR interim review.</td>
<td>Budget to be reassessed following MCR Interim Review.</td>
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<td>Implementation</td>
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<td>Project Complete</td>
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<td>COLUMBIA MED COL JUVENILE STURGEON RECOLONIZATION RISK</td>
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<td>COLUMBIA LOW COL ADULT STURGEON POPULATION MONITORING</td>
<td>Direct Management</td>
<td>3,021,123</td>
<td>829,175.03</td>
<td>Efficiencies found in direct management due to current approach to delivery of CLBMON 28, 29 and 30 using internal model</td>
<td>Budget to be reassessed based on the reassembly of the ecological risk assessment.</td>
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<td>COLUMBIA LOW COL OPPORTUNISTIC ASSESSMENT OF HIGH FLOW EVENTS</td>
<td>Direct Management</td>
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<td>COLUMBIA MCR EFFECTS OF FLOW CHANGES ON INCUBATION AND EARLY REARING STURGEON</td>
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<td>11,345.38</td>
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<td>Implementation</td>
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<td>COLUMBIA MCR EXPERIMENTAL AQUACULTURE</td>
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<td>COLUMBIA MCR UPGRADE HATCHERY</td>
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<td>Efficiency found in management of related culture activities. Reforecast approved budget following completion of new culture contract</td>
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<td>Implementation</td>
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* Red values in parentheses denote overage.