Columbia River Project Water Use Plan
Columbia White Sturgeon Management Plan

Kinbasket Sturgeon Recolonization Risk Assessment and Habitat Suitability

Implementation Year 2

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Executive Summary

There is interest in focusing on Kinbasket Reservoir and its large river tributaries as a potential recovery area for Columbia River White Sturgeon, which are listed as endangered under the Species at Risk Act (SARA). The term recovery refers to the attainment of a population level that ensures the persistence and viability of a naturally producing population. This report summarizes the results of a study designed to determine whether there are suitable spawning and free embryo hiding habitats available in the lower reaches of major tributaries to Kinbasket Reservoir (study area).

Measurements of spawning and early life stage habitat parameters in the study area were compared to habitat conditions found in healthy sustainable White Sturgeon populations elsewhere (Fraser and lower Columbia Rivers). Populations with natural recruitment have been reported spawning in both braided and confined reaches immediately upstream of a significant floodplain area in flows ranging from 400 to 10000 cms. In braided reaches, sturgeon spawn in side channels over small substrates of gravel and sand, with moderate-velocities of 1.3 to 2.2 m/s, average depths of 3.4 m (range = 1.4 to 5.0 m) and temperatures of 14.4 ^{o}C. In confined reaches, sturgeon spawn at similar velocities (averages from 1.4 to 2.1 m/s) and temperatures (average = 14.0 ^{o}C) but at greater average depths of 6.0 m (range = 4.0 to 23.0 m), and over larger bed materials of cobble and boulder. While conditions in the lower reaches of most large tributaries to Kinbasket Reservoir were generally unfavourable (e.g., maximum daily water temperatures averaged 7.0 to 9.0 ^{o}C), the Columbia River immediately upstream of the Kinbasket reservoir appeared to meet the parameters required for spawning.

The upper Columbia River has sufficient and prolonged scouring flows (maximum mean daily 1300 cms; 40-60 days mean flows > 500 cms) that approach sturgeon spawning flows in the Nechako (pre-dam) and Kootenai Rivers, providing freshly deposited and/or scoured substrates for incubating eggs and free-embryo hiding habitats. The unique and extensive wetland area between Radium and Donald allows the upper Columbia to be significantly warmer than other large river tributaries in the Kinbasket region and temperatures are optimal for sturgeon egg incubation and rearing (14-16^{o}C).

Unlike the lower Kootenai and impounded sections of the Lower Columbia River, the upper Columbia River was free of organochlorines (PCB's), which adversely affect the growth and reproductive physiology of sturgeon. With the exception of the sediment arsenic at Golden, the region also appears free of any metal contaminants that would impede the hatching and early development of White Sturgeon eggs and larvae. *In situ* egg survival rates at Redgrave (range 36-73%) were comparable to field studies reported elsewhere in the Columbia River. In addition, this region offered suitable food types (crustaceans and Diptera pupae and larvae) and sizes (< 4mm) for the onset of exogenous feeding and subsequent developmental stages.

The approximately 40 km of river from Golden (at the Kicking Horse River) downstream to Redgrave had mean depths (2.8-6.45 m), near bottom velocities (0.82 to 2.31 m/s), substrates (gravel/sand/cobble) and turbidities (mean 13-126 NTU) sufficient to support spawning adults and the subsequent early life stages. Because fluvial processes and channel morphology are unaltered in the upper Columbia, there is an abundance of eddy and side channel habitat dominated by gravel, sand and silt substrates and a diversity of hydraulic conditions. It is this diversity of moderate velocity gravel spawning beds

immediately adjacent to velocity depositional areas (0.5-1.5 m/s) that offers suitable larval and juvenile habitats within the upper Columbia River, particularly the meandering reach from Golden to Donald. In the only reporting of White Sturgeon spawning in an unregulated river (i.e., Fraser River), six spawning sites were identified over two years within 60 rkm. Five of these sites were in side channels of the meandering reach and one in the main channel of the confined reach.

Though sediment deposition is a mortality factor for White Sturgeon embryos, given 1) egg survival rates in the confined reach of the study area, 2) the high sediment levels measured at spawning and incubation sites in the Fraser River, and 3) the high, sustained optimal flow and temperature regime of the upper Columbia River, eggs incubated in the meandering reach may not be impeded by the high suspended sediment. This fact, combined with access to extensive lacustrine foraging habitat with abundant prey (e.g., 8-11 million Kokanee), and suitable adult depths, temperatures and substrates in Kinbasket Reservoir, offers the potential for establishment of a self-sustaining population of Columbia River White Sturgeon.

Acknowledgements

The Kinbasket Reservoir White Sturgeon habitat assessment was funded by BC Hydro. This project is a Columbia River Water Use Plan (WUP) initiative implemented by BC Hydro, as specified in the Provincial Comptroller of Water Rights Columbia River WUP Order. James Crossman, BC Hydro project manager, is gratefully acknowledged for his assistance and support in the delivery of this program. James Crossman and Guy Martel of BC Hydro conducted field visits and editorial reviews to provide quality assurance in the data.

Bill Green, Jaime Cristales, and Jon Bisset of CCRIFC (Canadian Columbia River Inter-Tribal Fisheries Commission) are acknowledged for their contributions to the management and implementation of this program. Westslope Fisheries Ltd. biologist Scott Cope along with CCRIFC technician Mark Thomas conducted the field surveys. José Galdemez of Lands and Resources, Ktunaxa Nation Council, provided mapping and GIS services.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

During the Columbia River Water Use Plan (WUP) process, the Consultative Committee (CC) identified fish species of management priority to help focus discussions around which ecological functions were most critical with respect to water management issues. The Committee agreed that one focus of fish management in the Columbia River mainstem should be White Sturgeon (*Acipenser transmontanus*).

White Sturgeon in the Canadian portion of the Columbia River were listed as endangered under the Species at Risk Act (SARA) in 2006. There are an estimated 900-1400 individuals downstream of Hugh Keenleyside Dam to the international border and about 50-90 in the Arrow Lakes (Irvine et al. 2007; Golder Associates Ltd. 2006).

Anecdotal evidence indicates that White Sturgeon were present in the Columbia River at least as far upstream as the original (pre-flooded) Kinbasket Lake prior to the construction of Mica Dam (Prince 2001). However, during a three year (2008-2010) sturgeon inventory program on Kinbasket (CLBMON-19), sturgeon were not encountered. Thus, it appears that White Sturgeon are now either extirpated or very rare in the reservoir (Prince 2011).

Almost all populations of White Sturgeon are undergoing recruitment failure and multiple competing hypotheses exist regarding the mechanisms most likely to impede recruitment. The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) Technical Working Group (TWG) undertook a complete review of recruitment failure hypotheses for Columbia River White Sturgeon (Gregory and Long 2008) and determined that the most probable causes of failure in the lower ColumbiaRiver were a lack of:

a) Spawning conditions with suitable depths, velocity, substrate, temperature and turbidity;

b) free-embryo hiding habitat, where predators can be avoided (similar parameter types as required for spawning);

c) larval habitat (similar parameters to above, but including suitable types and abundance of prey); and

d) juvenile rearing habitat (similar parameters to above).

Populations with good to excellent recruitment have been reported spawning in both braided and confined reaches immediately upstream of a significant floodplain area. In braided reaches, sturgeon spawn in side channels over small substrates of gravel and sand, with moderate velocities of 1.3 to 2.2 m/s, average depths of 3.4 m (range = 1.4 to 5.0 m) and temperatures of 14.4 ^{o}C (Perrin et al. 2003). In confined reaches, sturgeon spawn at similar velocities (averages from 1.4 to 2.1 m/s) and temperatures (average = 14.0 ^{o}C) but at greater average depths of 6.0 m (range = 4.0 to 23.0 m), and over larger bed materials of cobble and boulder (Parsley et al. 1993, Perrin et al. 2003).

Unlike the impounded lower reaches, the Columbia River upstream of Kinbasket Reservoir has an unregulated hydrograph and thermal regime. This fact, combined with suitable substrate and access to extensive lacustrine foraging habitat (Kinbasket Reservoir), offers the potential for establishment of a self-sustaining population of Columbia River White Sturgeon.

There is interest in evaluating Kinbasket Reservoir as a potential recovery area for Columbia River White Sturgeon. The term recovery refers to attainment of a population level that ensures the persistence and viability of naturally producing populations of White Sturgeon (BC Hydro 2008). Some feasibility studies have already occurred in the form of ecological risk assessments and public discussions to gauge the level of support for the activities (Westslope Fisheries Ltd. and CCRIFC 2005, CCRIFC 2005a and CCRIFC 2005b).

This study is designed to continue the process of assessing the potential for White Sturgeon recolonization of Kinbasket Reservoir and upper Columbia River. It is unclear whether the habitats in these areas are suitable for the survival and growth of embryos, free embryos, larvae, and juveniles (Management Question b, BC Hydro 2008). If suitable habitats are present, ecological risk factors related to release of hatchery produced juveniles should be addressed (Management Question a), and it should be determined whether the program can provide large enough numbers of juveniles to ensure a high probability of establishing a population in the upper Columbia River (Management Question c, BC Hydro 2008).

The objective of the current study is to determine if the habitat in the upper Columbia River can provide conditions that support early stages of the White Sturgeon's life cycle (Management Question b).

Management Question b): 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? (BC Hydro 2008)

The methodological approach of this study is descriptive rather than experimental, and as such, is designed to provide baseline information rather than test specific hypotheses. During the Kinbasket Reservoir sturgeon inventory program (CLBMON-19), the best candidate areas with preferred sturgeon spawning and early life stage habitat characteristics were identified immediately above the reservoir in the upper Columbia River downstream of Nicholson (Prince 2011). Measurements of spawning and early life stage habitat parameters in these areas (i.e., downstream of Golden) were used for comparison with habitat conditions found in healthy sustainable White Sturgeon populations in the regulated US Columbia River and unregulated Canadian Fraser River to determine if the region contains habitats that could support and sustain White Sturgeon embryos, larvae and juveniles.

Key Water Use Decisions

During development of the Columbia River Water Use Plan, efforts were made to explore the effects of dam operations on White Sturgeon habitat throughout the Columbia River system. The results of this study will inform a decision by the Comptroller of Water Rights to authorize formal out-planting of juvenile sturgeon into Kinbasket Reservoir or the upper Columbia River and assess habitat use and survival (CLBMON-25). In the longer term, the results are expected to contribute to future reviews about the value of continued efforts to establish a sturgeon population in the mid Columbia River downstream of the Revelstoke generating station (REV) in comparison to establishing another recovery area upstream of the Mica dam. If the upper area is chosen for stocking effort, this project will provide an assessment of the risk associated with that plan, and will provide at least the basis of a conservation aquaculture supported population that would establish sturgeon in Kinbasket through hatchery stocks.

Water use decisions regarding the operation of Kinbasket Reservoir are partly contingent on the findings of this project. If the reservoir is deemed suitable for a program aimed at establishing either a self-sustaining population or fail-safe population of sturgeon, water use decisions regarding the reservoir may be reviewed. Trade-offs between water management for downstream uses and management for sturgeon (and other species) may be required (BC Hydro 2008).

1.1. Study Area

Mica Dam and its generating station are located on the Columbia River about 130 km upstream of Revelstoke Dam and the City of Revelstoke, in southeastern British Columbia (Figure 1.1). Mica Dam was built to provide flood control and flow regulation with the benefits of power generation at Mica and increased power generation at downstream installations as part of the Columbia River Treaty. Mica Dam is the largest of the Columbia River Treaty projects and is a 197 m high earth-filled structure with a crest elevation of 762.0 m above sea level. Construction began in 1967 and the dam was declared operational in 1973.

Kinbasket Reservoir was formed by construction of the dam and first reached full pool in 1976. It is 216 km long, and has a maximum surface area of 43,200 ha. Prior to inundation, Kinbasket Lake was 13 km long and had an area of 2,250 ha. The original, smaller Kinbasket Lake was named in 1866 after Kinbasket, a chief of the Secwepemc (Shuswap) First Nation (Dehart 2006). The reservoir was originally called McNaughton Lake until 1980, at which time its name was changed to Kinbasket Reservoir. The reservoir has two reaches, referring to the river valleys flooded by the dam. The Columbia reach extends about 100 km from the 'Big Bend' of the Columbia River southeast to Donald Station. The Canoe Reach extends about 90 km in a northwesterly direction to Valemount (Figure 1.1). This area was historically called 'the Big Bend Country', dating back to David Thompson's historic 'discovery' and exploration of the Columbia River and the establishment of the Pacific fur trade route (1810-11)(Hopwood 1971).

Under the existing water licenses, Kinbasket Reservoir is licensed to operate between a minimum pool elevation of 707.14 m and a maximum elevation of 754.38 m, a vertical drawdown of 47.24 m. In recent years (1994 – 2006), the reservoir has normally operated between an elevation of 714 m and full pool (754.38 m), creating an operating range of 40 m (RL&L 2001, Prince 2011).

Within the Columbia River, two distinct reaches were targeted for sampling in 2012 and are briefly described below.

Meandering Reach - Golden to Donald: meandering channel with extensive off channel habitat in the form of sloughs and wetlands. Moderate turbidity, gravel/sand substrate.

Confined Reach - Donald to Lower Redgrave: confined channel, bedrock canyon with course substrate (boulder/cobble) and high turbidity. Transition area at Quartz Creek (Site 4Q, Figure 1.1) is seasonally inundated by Kinbasket Reservoir filling.

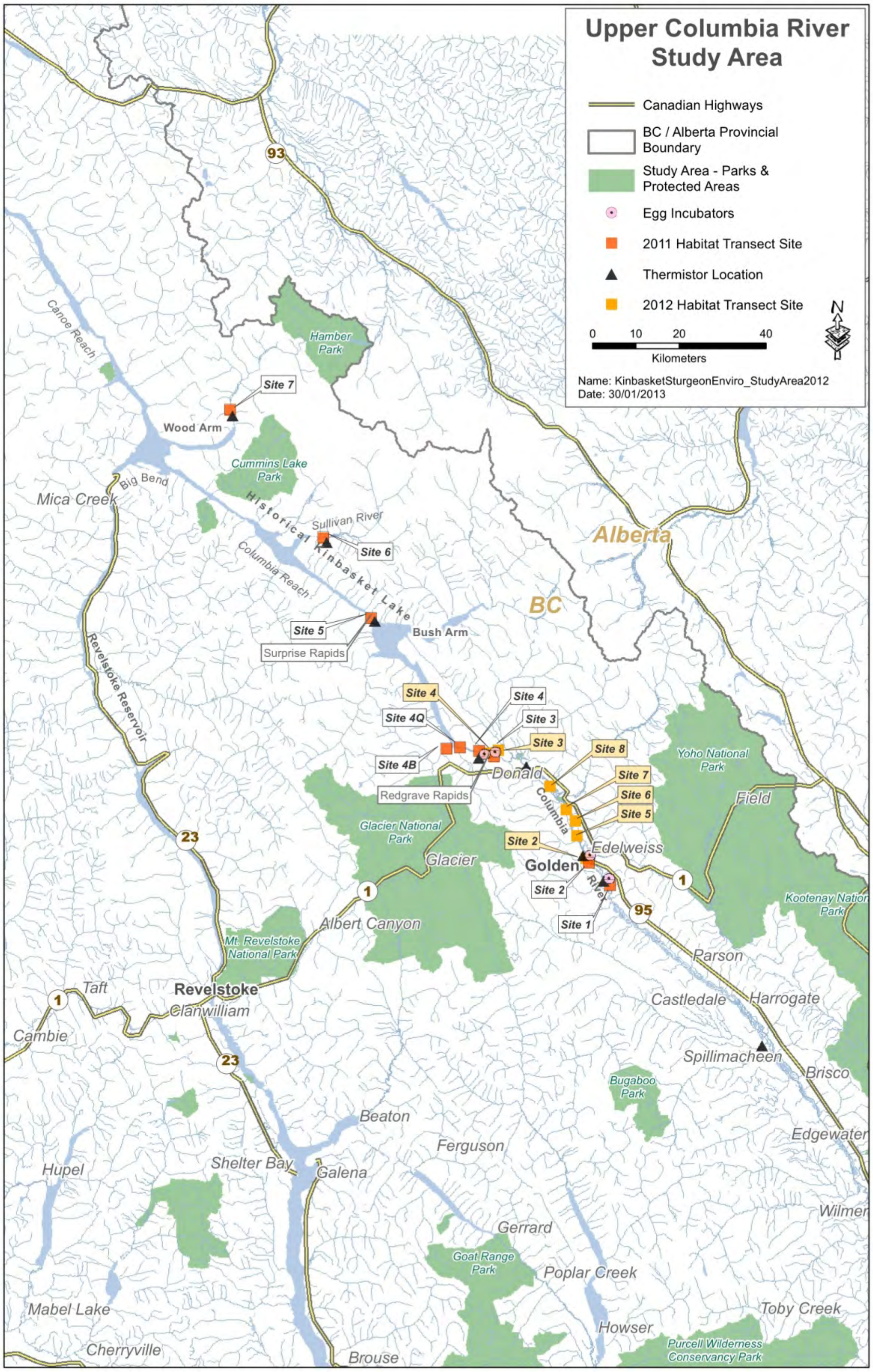

Figure 1.1 Study area showing habitat data collection sites. Habitat characteristics assessed at these sites included depth, temperature, substrate and velocity.

2. Methods

The upper Columbia River White Sturgeon habitat assessment includes the following components, each of which is provided with a rationale and described more fully throughout this section.

- Hydrometric data (discharge and elevation)
- Temperature monitoring (8 locations)
- Cross channel transect measurements (depth, substrate, velocity, turbidity)
- Contaminant analysis (water and sediment)
- Egg survival (*in situ* experiment)
- Food availability (benthos analysis)

2.1. Hydrometric Data

Water Survey of Canada provided the preliminary mean daily discharge data for 2012 on the Columbia River at Donald B.C. (Station No. 08NB005). This data is still subject to review and therefore may contain errors. Archived hydrometric data for the upper Columbia River and the Nechako River at Vanderhoof (Station No. 08JC001, downstream of the Kenny Dam) were obtained from the WSC database HYDAT. The United States Geological Service (USGS) provided hydrometric data for the Kootenai River at Porthill, Idaho (Station No. 12322000 located at the US/Canada border and downstream of the Libby Dam) and BC Hydro provided data on Kinbasket reservoir level (average daily elevation (m) as measured in the Mica forebay).

2.2. Temperature

Temperature measurements were focused in reaches in the upper Columbia River where there appeared to be suitable and contiguous spawning, larval and juvenile sturgeon habitats (CLBMON-19, Prince 2011, Prince 2012). Within the Columbia River, seven locations were identified for detailed measurements: five in the meandering reach from Golden to Blaeberry and two in the confined reach at Donald and Redgrave.

Water temperature was recorded with two Tidbit V2™ loggers (replicates) at seven sites (Figure 1.1). Temperatures were recorded every 15 minutes and summarized to provide daily means. All temperature loggers were placed on the bottom, attached to either a concrete anchor or to an egg incubation tray (Section 2.5 Egg Survival). In addition, surface temperatures (measured with an alcohol thermometer and YSI 600-QS multimeter) were recorded at each location (Table A1, Appendix A).

2.3. Habitat Characteristics

Like temperature, habitat measurements were focused in reaches where there appeared to be suitable and contiguous spawning, larval and juvenile sturgeon habitats (Prince 2011, Prince 2012). Building on results from the 2011 program, sampling in 2012 was restricted to the area of Columbia River from Golden downstream to Redgrave. Due to logistical constraints and safety concerns (bridge construction), Donald was not sampled.

Five georeferenced cross channel transects were surveyed at each site (Golden, Kicking Horse, Moberly Main Channel, Moberly Side Channel, Blaeberry, and Upper Redgrave). Each transect contained 3-5 points on a line perpendicular to flow and banks representing right bank (RB), right midbank (RM), thalweg, left midbank (LM), left bank (LB). Specific transect locations were determined by assessments of bathymetric profiles, flows (moderate velocity and/or eddy preferred) and substrate (sand and cobble preferred).

At each point location within a transect, measurements of depth, substrate, velocity, and turbidity were collected. Depth was recorded using a Lowrance 2020 sounder. Substrate was viewed with a drop camera (Kootenai Swiftwater™) complete with lighting and 30 m cable. Velocity measurements were collected using a Price AA model 1210 current meter. This type of instrument is used by Water Survey of Canada and is recommended as it is accurate enough to produce a stage-discharge relationship within a ± 7% margin of error for Class A data (Anon. 1998). The National Calibration Institute for Environment Canada in Burlington Ontario calibrated the meter for use with a 50 lb. sounding weight and a top-set wading rod. The meter was lowered to 0.2 and 0.8 of the total water depth to calculate a mean water column velocity. In addition, measurements of flow at the river bottom were also collected, though debris and boulder hazards limited the number of bottom and near bottom (0.8 depth) velocity measurements (Appendix A). Turbidity (surface) was analyzed in the field using a Lamotte 2020 turbidity meter. Detection limits of the Lamotte meter are 0.05 NTU's (nephelometric turbidity units) with an accuracy of ± 2% below 100 NTU. The Lamotte meter was calibrated using factory specific solutions of 1.0 and 10.0 NTU's and distilled water before processing each set of samples. Values of depth, velocity and turbidity data were summarized to provide means for the reach and substrate summarized as a proportion. Measurements of water temperature, dissolved oxygen (DO), conductivity, and pH were collected once per transect using a YSI 600-QS multimeter and a 61 m cable. All habitat measurements are presented in Table A1, Appendix A and are summarized by transect (average) and reach (mean and standard deviation).

2.4. Contaminant Analysis

Introduction of contaminants in the Columbia River has been implicated as a possible cause of poor reproductive success for White Sturgeon. The adhesiveness and permeability of White Sturgeon eggs following fertilization increases their susceptibility to contaminants associated with water, sediment and organic matter (Kruse and Scarnecchia, 2002a). To assess these concerns, water and substrate/soil samples were collected in reaches where there appeared to be suitable spawning and free embryo sturgeon habitats (Prince 2011). Sample locations were chosen at random during transect habitat measurements in Sites 1-7 (Figure 1.1). The specific location (i.e., transect number and channel point) of each water and sediment sample is shown in Table A1 (Appendix A). Water samples were collected at 0.8 total depth with a 2.2 liter Beta sampler. Sediment samples were collected with a Petite Ponar dredge. Replicate water and soil samples were collected for quality control (Appendix C). Samples were analyzed for a standard suite of total metals (Appendix C), PCB's, copper, turbidity, and total suspended sediment (TSS) by Maxxam Laboratories Inc. Burnaby BC. Maxxam Laboratories Inc. is a member of the CAEL (Canadian Association of Eligible Laboratories) and submits regularly to government testing and audits.

2.5. Egg Survival

To determine whether White Sturgeon eggs can survive to hatch in the Upper Columbia River, 2400 hatchery fertilized White Sturgeon eggs were transported on July 26, 2011 and July 18, 2012 from the Kootenai Trout Hatchery near Cranbrook, B.C. to the upper Columbia River near Golden, BC. Six sites were assessed: Golden, Moberly Side channel, Blaeberry, Below Kicking Horse, Upper Redgrave, and lower Redgrave. Eggs used in the experiment were from the conservation aquaculture program currently in place for the Columbia population, with adult broodstock obtained in the lower Columbia River. To minimize the risk of egg or larval loss from the experiment, White Sturgeon eggs were placed within enclosed incubation trays. An incubation tray consisted of a thick Plexiglas sheet with 100 wells distributed in a rectangular grid pattern, with a single egg being placed in each well. Trays were loaded with fertilized eggs from a single maternal family at the hatchery immediately following de-adhesion procedures. Two sheets of similarly sized and perforated Plexiglas, with plastic screen (1 mm^2 holes) glued to one side, were placed on either side of the tray to seal the eggs within (enclosure). For replication, six enclosures (100 eggs each) were fastened together with rebar and anchored at each site. Thermistors were attached to egg plates to capture site specific incubation temperatures.

2.6. Food Availability

Another possible cause for recruitment failure in White Sturgeon may be a lack of suitable prey availability (~100 µm) at the onset of exogenous feeding (Muir et al., 2000). To address this issue, benthos samples were collected in reaches where there appeared to be suitable free embryo and larval sturgeon habitats (Prince 2011). Sample locations were chosen at random during the transect habitat measurements in Sites 2-8 (Figure 1.1). The specific location (i.e., transect number and channel point) of each benthos sample is shown in Table A1 (Appendix A). Benthos was sampled with a 500 micron Serber sampler by scarifying substrate for 60 seconds in depths less than two meters and using a Petite Ponar where depths were greater than two meters. Samples were preserved in alcohol for subsequent identification and measurement under a microscope. Aquatic invertebrate biologist Dr. Misun Kang of Vast Resourses Inc. (Cranbrook B.C.) conducted a qualitative analysis the benthos to identify the type (genus) and size (3 categories: 125 µm, 1 mm and 4 mm) of available food types.

3. Results and Discussion

3.1. Spawning and Free Embryo Hiding Habitats

3.1.1. Hydrology

A key reason the upper Columbia River is thought to have potential for establishment of a self-sustaining population of White Sturgeon is its unregulated hydrograph (Figure 3.1). Flow alteration is widely accepted as a causal factor in the species decline throughout its distribution. The flow regime of the upper Columbia River is comparable to most interior systems with a snowmelt dominated peak occurring in late spring (May-July) and is similar to other White Sturgeon spawning flows in the upper Nechako (pre-Kenny Dam) and Kootenai Rivers (post-Libby Dam, Figure 3.1; Note: the Kootenai River is known as the Kootenay River in Canada).

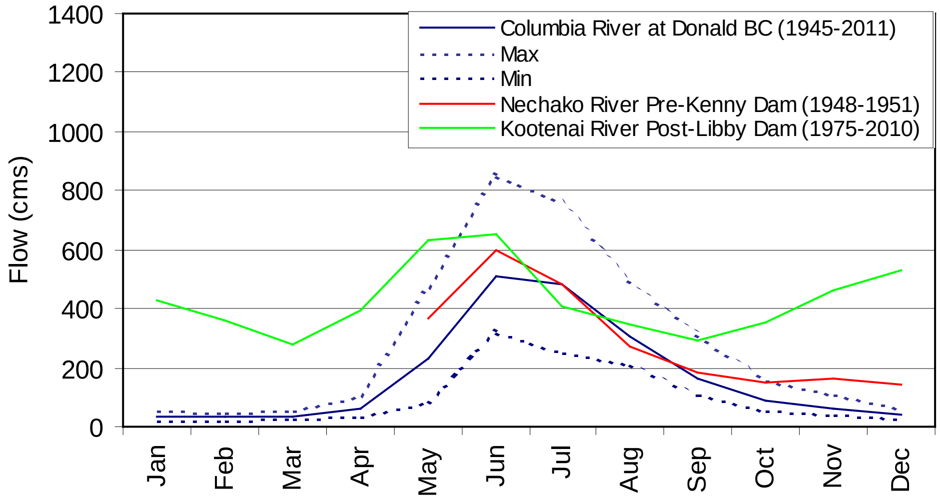

Figure 3.1 Mean monthly discharge (cms) for the upper Columbia River at Donald, BC. Dashed lines represent average maximum and minimum flows for the same period. Average monthly flow data for the Nechako River at Vanderhoof and the Kootenai River at Porthill, Idaho represent flow conditions for sturgeon spawning populations at their most upstream distribution.

Before construction of the Kenny Dam (1952), annual Nechako River flows in the sturgeon spawning reach peaked in May and June and averaged 550-600 m^3/s (mean monthly; Figure 3.1). Sturgeon recruitment continued with some regularity post dam until 1967 when it dramatically declined and the peak hydrograph shifted to August averaging 100-150 cms (McAdam et al. 2005). Maximum flows in the Kootenai River post Libby Dam (1972, Figure 3.1) still occur in spring but at a reduced rate compared to pre-dam flows (1700 to 2800 cms, Duke et al. 1999; Paragamian et al. 2001). Spawning and egg deposition have been observed in most years for both populations under current conditions; but there is negligible survival of eggs and larvae, which is attributed to a lack of scouring flows that remove the fine sediment overburden (McAdam et al. 2005 and 2012, Paragamian et al. 2009).

Exposure to overlying sediment depths of only 5 mm has been shown to reduce sturgeon egg survival to 50% after four days and to less than 20% after nine days or longer (Kock et al.

2006). In Kinbasket Reservoir, rising water levels from May through August (known sturgeon spawning period) result in the lower tributary reaches being inundated (backwatered) and substrates become overlain with up to 0.5 m of silt. Eggs deposited within the inundation zone of large tributaries would suffocate as glacial fines settle out of suspension (Prince 2011). A sustained period of high discharge and relatively long-duration is believed to be required to prevent egg suffocation (Paragamian et al. 2001) and to unveil the interstitial habitats of coarse substrates (McDonald et al. 2010) that serve as predator refuges for hatchling free embryos (Kynard et al. 2010).

Historically, scouring flows (mean daily) in the sturgeon spawning reach of the Nechako River averaged 687.25 cms (range 634-733 cms) and 100% of peak events occurred between May 15 and July 15 (Figure 3.2). During the post-dam period of variable recruitment from 1953-1967, the average peak daily flow was reduced by 43% to 393.73 cms; yet, 40% of scouring events were > 500 cms and 73.3% of peak events still occurred between May 15 - July15 (Figure 3.2). While the average peak daily flow remained similar post 1968 (351.84 cms), only 9.3 % of scouring flows were greater than 500 cms, 84% of peak events occurred outside the normal May 15 – July 15 maximum flow period (Figure 3.2), and recruitment became negligible (McAdam et al. 2005). The spawning timing of White Sturgeon on the descending limb of the annual hydrograph may reflect adaptations to avoid egg burial during periods of bed mobility and allow freshly deposited and/or scoured coarse bed materials to be used for spawning and free embryo hiding. With average peak daily flows of 687.73 cms (1945-2011), 93% of scouring events > 500cms, and 97% of peak events between May 15 and July 15, the upper Columbia River at Donald, BC mirrors the scouring flow conditions in the sturgeon spawning reach of the Nechako River when recruitment occurred with some regularity (Figure 3.2).

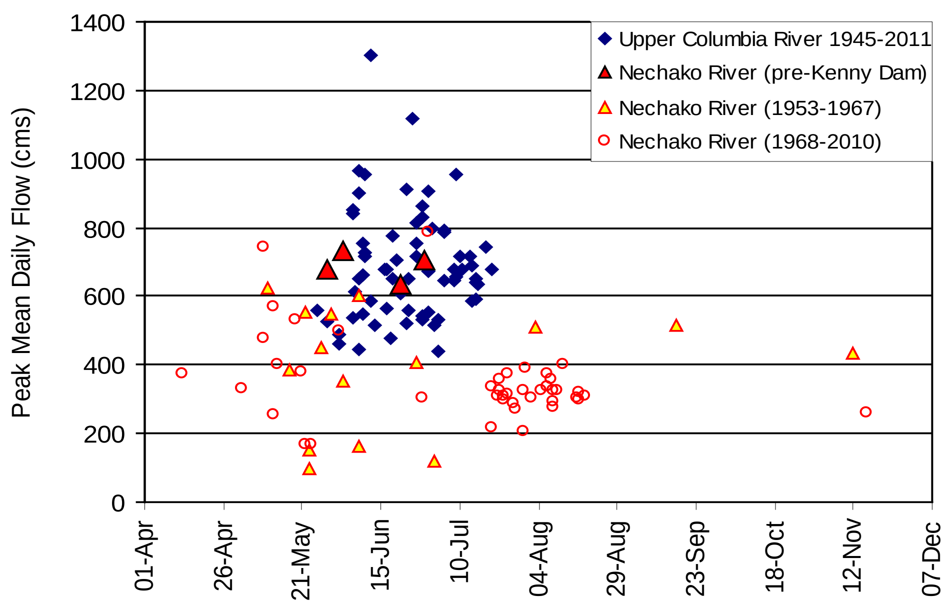

Figure 3.2 Peak mean daily flow for the upper Columbia River (1945-2011) at Donald, BC. Average peak daily flow data for the Nechako River at Vanderhoof from 1953 to 1967 represent flow conditions for years with variable recruitment. By 1968, recruitment became negligible (McAdam et al. 2005).

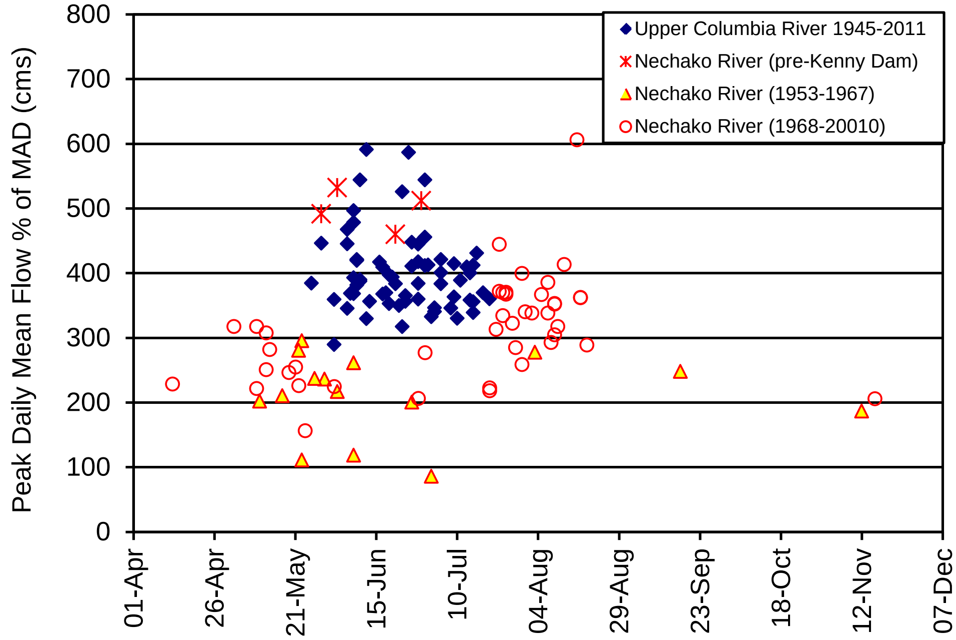

Figure 3.3 Peak mean daily flow as a percent of mean annual dishcharge (MAD) for the upper Columbia River (1945-2011) at Donald, BC. Average peak daily flow data for the Nechako River at Vanderhoof from 1953 to 1967 represent flow conditions for years with variable recruitment. By 1968, recruitment became negligible (McAdam et al. 2005).

Since sediment transport capacity of rivers adjusts to their geomorphological setting and flow regime, biologists often prefer to examine peak flows as a function (i.e., percentage) of mean annual discharge (MAD; Figure 3.3). In the Nechako, peak flows as a percent of the MAD increased during the period of null recruitment in comparison to years with recruitment (1953-1967); however, these peak flows were reduced in magnitude and occurred outside the normal maximum flow period (Figure 3.2).

A maximum flow threshold is an important requirement to sufficiently scour substrates for use by sturgeon free embroys. Hydraulic modelling and direct observations of the spawning reach in the Kootenai River showed that flows of 1300 cms or more were sufficient to scour the bed and expose limited patches of suitable substrate that were previously buried under 0.5 to 2.0 m of sand (Paragamian et al. 2009). The sediment transport model used the 1974 hydrograph to evaluate erosion and deposition in the sturgeon spawning reach as it was the only year with significant natural recruitment during the post-dam period (Figure 3.4; Partridge 1983; Paragamian et al. 2009). While the peak mean daily flow in 1974 was only 237% of MAD, which is low in comparison to peaks pre-Libby dam (Figure 3.5), the flow reached a mean daily discharge of 1549 cms and spent 15 days above 1300 cms during the normal maximum flow period (Figure 3.4).

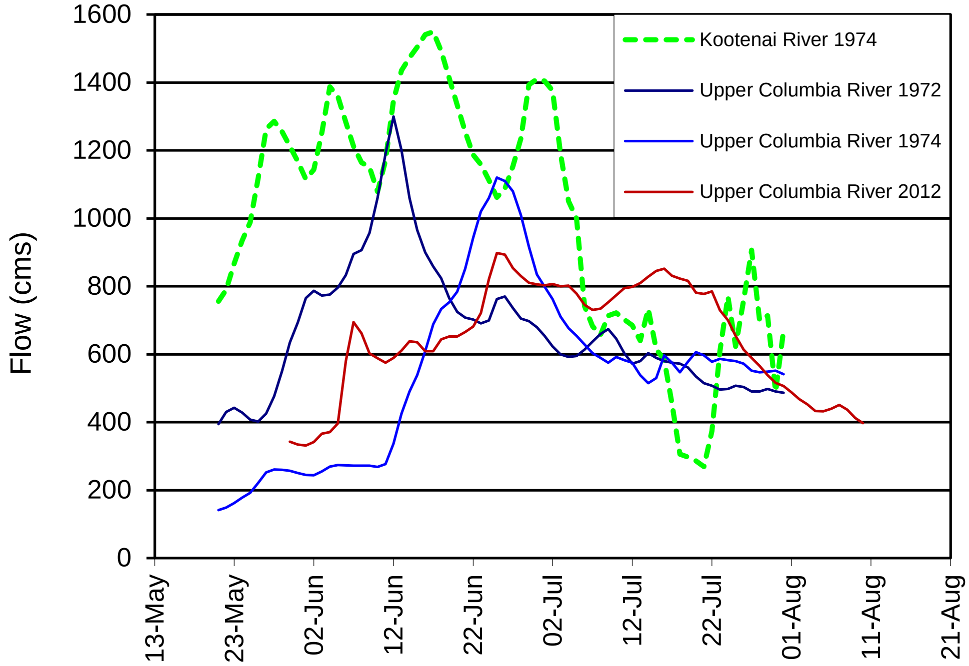

Figure 3.4 Peak mean daily flow for the upper Columbia River (1972 and 1974) at Donald, BC. Mean daily discharge data for the Kootenai River at Porthill, Idaho 1974 represent flow conditions for only post dam year with significant recruitment.

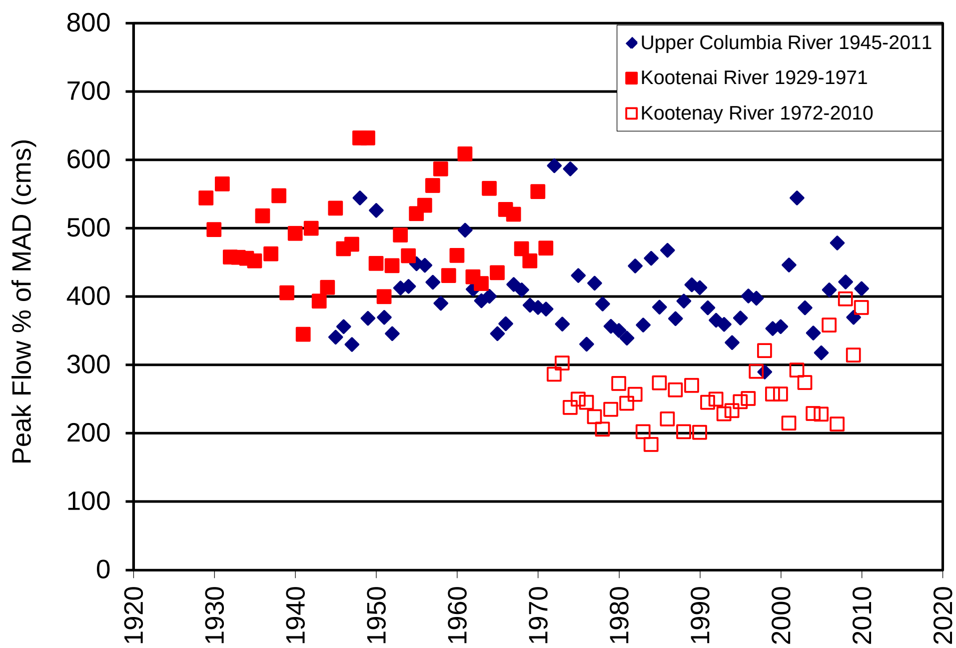

Figure 3.5 Peak mean daily flow as a percent of mean annual discharge (MAD) for the upper Columbia (1945-2011) and Kootenay (1929-2010) rivers. Libby Dam was completed in 1972 and fully operational by 1974.

The upper Columbia River peak mean daily flows range from 439 to 1300 cms and occur from late May to mid July (Figure 3.2). Given 1) the similarity of annual and peak flows (500 cms) to Nechako conditions when recruitment occurred with some regularity (Figure 3.2), 2) scouring flows that approach those required to overcome fine sediment overburden in the Kootenai River (1300 cms, Figure 3.4), and 3) the duration (40-60 days > 500 cms, Figure 3.4) of peak flows, the upper Columbia River study area appears to offer the flow regime necessary to remove fines and prevent suffocation of eggs and embryos.

3.1.2. Temperature

Self-sustaining populations of White Sturgeon in the lower section of the Columbia River (below Bonneville Dam) require average temperatures of 14.0 ^{o}C for spawning (range = 10.0 to 18.0 ^{o}C, Parsley et al. 1993, Table 3.1). In the unregulated Fraser River sturgeon spawn at comparable average temperatures of 14.4 ^{o}C ranging from 11.5 to 18 ^{o}C (Perrin et al. 2003). Sturgeon have been documented to spawn in cooler waters in the Canadian portion of the Columbia River near Revelstoke, (9.2 to 10.9 ^{o}C, Golder 2012) and the Kootenai River (8.5-12.0^{o}C; Paragamian et al. 2001); however, these populations are impounded and experiencing recruitment failure. Similarly, White Sturgeon that spawn in warmer temperatures up to 21.0^{o}C in the Canadian portion of the Columbia River near Waneta also have negligible recruitment (Hildebrand et al. 1999). The cooler water temperatures lengthen the incubation and larval rearing period and therefore the duration of susceptibility to moving sediments and predation by several days to weeks (Kock et al., 2006, Parsley et al. 2011) while temperatures above 18.0^{o}C are associated with increased mortality and abnormal development (Conte et al., 1988). The optimal temperature range for successful White Sturgeon egg incubation ranges from 14.0 to 16.0 ^{o}C (Wang et al. 1985, Table 3.1).

Table 3.1 Average spawning temperatures (range) required for White Sturgeon egg incubation in relation to mean daily water temperatures in the Kinbasket region study area during the known sturgeon spawning period (15 June to 15 August 2012).

Optimal[1] (Wang et al. 1985)	**Fraser River** (Perrin et al. 2003)	**Lower Columbia** (Parsley et al. 1993)	**Nicholson** (15 Jun-15 Aug)	**Golden** (15 Jun-15 Aug)	**Donald** (15 Jun-15 Aug)	**Redgrave**[2] (15 Jul-15 Aug)
15.0 (14-16)	14.4 (11.5-18.0)	14.0 (10.0-18.0)	16.2 (12.0-18.6)	16.7 (12.6-19.5)	15.2 (11.5-17.7)	14.6 (13.3-15.5)

[1] Cultured white sturgeon eggs

[2] Redgrave 2011

Water temperatures in the upper Columbia River averaged 14.0^{o}C by mid-June and remained at or above that threshold until September (60-90 day period, Figure 3.6). The 2012 data are consistent with previous temperature profiles (Prince 2012) and those collected during the sturgeon inventory program in 2010 (CLBMON-19, Prince 2011). Temperature data were unavailable in 2012 for the Kicking Horse, Moberly side channel, Blaeberry and Redgrave sites due to sediment and debris deposition during freshet which prevented thermistor retrieval. Flows were 38% higher in 2012 than 2011 and the peak mean daily discharge in 2012 of 898 cms was the 9th highest on record since 1945 (Figure 3.6).

Temperatures in the upper Columbia follow the same pattern as the lower Columbia and Fraser Rivers, rising to a maximum of 18.0°C before falling below an average of 14.0°C in September during embryo and free embryo development periods (Parsley et al. 1993, Perrin et al. 2003). While temperatures in the upper Columbia River appear optimal for spawning and embryo development, temperatures in other large river tributaries to Kinbasket Reservoir (i.e., the Wood and Sullivan Rivers) were well below the threshold (Table 3.1; Prince 2011).

A key habitat feature of the upper Columbia is the wetlands that characterize the headwaters ranging from Canal Flats to Donald B.C. It is the longest (180 km) continuous wetlands remaining on the continent and covers 26000 hectares with a flood plain that ranges from 1-2 km in width (East Kootenay Plus website, 2012). The shallow depths (< 5m) of the Columbia River wetlands allow increased thermal conductance to the river thereby raising temperatures (Prince 2010, Appendix A). The increased temperatures reduce the solubility of oxygen while increasing the metabolic demands of aquatic life. The natural temperature cycle of the river is further increased in amplitude by anaerobic decomposition and is reflected in the reduced oxygen levels at Golden (8.4 mg/L) compared with values approaching saturation (over 12 mg/L) in the Sullivan and Wood Rivers (Prince 2012). This unique wetland habitat feature allows the upper Columbia to be significantly warmer than other large river tributaries in the Kinbasket region (e.g., Wood and Sullivan Rivers), many of which are directly fed by extensive glaciers and ice fields.

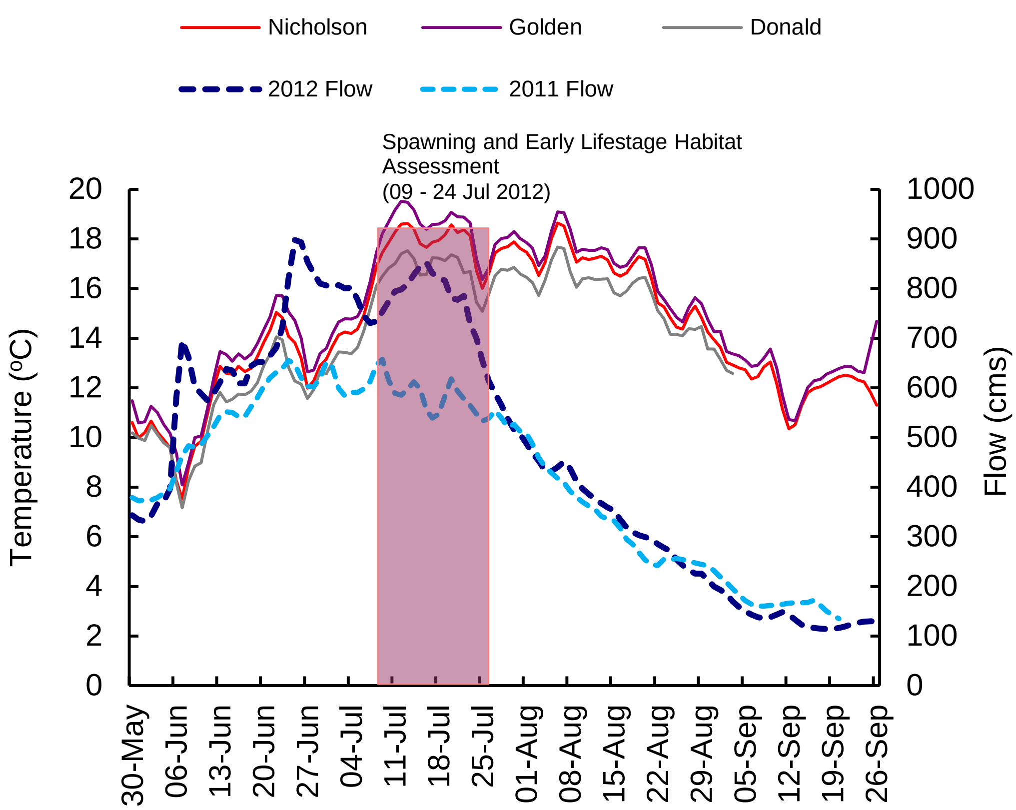

Figure 3.6 Mean daily temperature and flow data for the upper Columbia River (2012). Flows in 2012 were the 9th highest on record since 1945. Average daily temperature data were collected in habitat sampling reaches and flow data are from WSC St. No. 08NB005 at Donald, B.C. Flow data are preliminary/raw and may contain errors.

3.1.3. Habitat Characteristics

Self-sustaining White Sturgeon populations with recruitment have been reported spawning in both meandering and confined reaches immediately upstream of a significant floodplain area (Parsley et al. 1993, Perrin et al. 2003, Coutant 2004). Sites selected for habitat assessment in the upper Columbia River included locations within the meandering reach (Golden, Kicking Horse, Blaeberry, and Moberly side channel) and two locations within the confined reach (upper and lower Redgrave, Figure 3.7). Transect locations within each site targeted potential spawning and early life cycle rearing habitats (Figures B1 to B9, Appendix B). Habitat surveys within index sites in the upper Columbia River were conducted from July 09 to 24 on the descending limb of the hydrograph, one week earlier than the 2011 sampling. Mean daily flows were 38% higher in 2012 than during the previous sampling (range 618-380 cms) and ranged from 852 to 700 cms (Figure 3.6). This period corresponds with the sturgeon spawning period in the Fraser River from July 4 to August 8 (Perrin et al., 2003)

In meandering reaches of the Fraser River, sturgeon typically spawn in side channels over small substrates of gravel and sand, with moderate-velocities of 1.3-2.2 m/s, average depths of 3.4 m (range = 1.4 to 5.0 m) and temperatures of 14.4 ^{o}C (Table 3.2, Perrin et al. 2003). In the confined reach, Fraser River sturgeon spawned in the mainstem under similar conditions of depth and velocity, but over larger bed materials of cobble (40%), gravel (30%), and boulder (23%) (Table 3.2, Perrin et al., 2003).

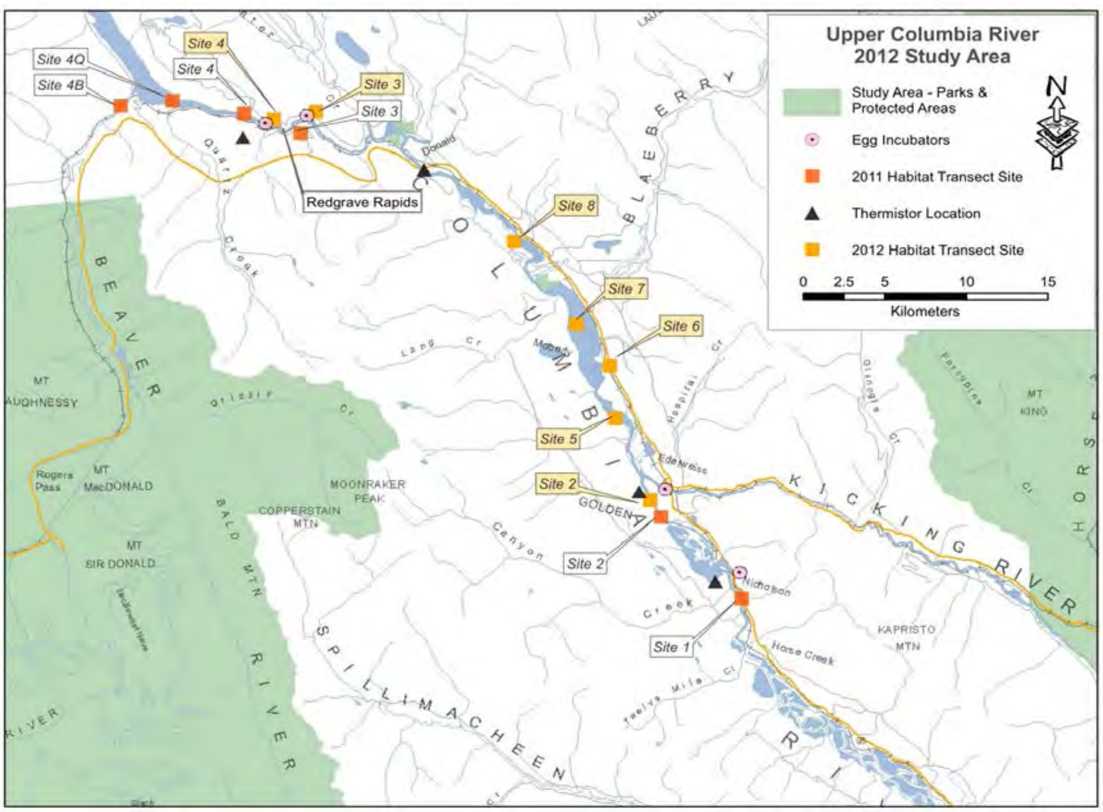

Figure 3.7 Upper Columbia River Study Area 2012 showing major tributary inputs (Blaeberry and Kicking Horse Rivers) and habitat reaches. Cross channel transects were sampled for habitat parameters in both the meandering (sites 2,5,6,7&8) and confined (sites 3&4) reaches of the Upper Columbia River.

Table 3.2 Mean (SD) habitat conditions in the Upper Columbia River in relation to sturgeon spawning habitats for self-sustaining populations in the Fraser and Lower Columbia Rivers. Values in parentheses separated by dashes represent ranges. Lower Columbia data are for newly spawned eggs only (i.e., before first cleavage).

	Fraser River		**Lower Columbia River**	**Upper Columbia River 2012**						
	(Perrin et al., 2003)		*(Parsley et al., 1993; McCabe and Tracy 1994)*	Golden Airport (Site 2)	Kicking Horse (Site 5)	Moberly (side channel) (Site 6)	Moberly (main channel) (Site 7)	Blaeberry (Site 8)	Upper Redgrave (Site 3)	Lower Redgrave (Site 4)
Channel Type	Meandering	Confined	Confined	Meandering					Confined	
Date	Jun 19-Jul 23 1998 and Jun 27- Aug 11 1999		Apr-Jul 1987-1991	Jul 09	Jul 13	Jul 15	Jul 14	Jul 19	Jul 11	Jul 11
Depth (m)	3.5 (0.5)	4.0 (1.1)	6.0 (4-23)	4.88 (1.9)	2.8 (1.75)	3.1 (0.57)	4.23 (1.5)	3.04 (1.01)	3.73 (0.8)	6.45 (2.6)
Velocity (m/s)										
Bottom			1.4 (0.60-2.40)	1.08 (0.5)	1.03 (0.15)	0.86 (0.2)	0.8 (0.2)	[a]	[a]	0.17 (0.1)
0.8	1.9 (0.40) (1.3 - 2.2)	2.1 (0.2)	2.1 (1.0-2.8)	1.21 (0.6)	1.08 (0.8)	0.82 (0.5)	1.14 (0.2)	[a]	2.15 (1.2)	1.6 (1.0)
0.8 maximum				2.08	2.12	1.45	1.39	2.12[b]	3.15	3.06
Substrate (%)										
Boulder	0	23	70	7	0	2	0	3	53	22
Cobble	27 - 10	40	23	17	15	13	2	37	28	11
Gravel	68 - 60	30	3	22	49	37	14	46	27	8
Sand	5 - 33	7	4	41	25	23	54	2	30	18
Silt/Clay	0	0	0	13	9	6	8	13	20	15
Bedrock	0	0	0	0	0	0	0	0	0	0
Temp (^{o}C)	14.4		14.0	18.0	17.1	14.3	16.0	12.5	14.3	14.9
Turbidity (NTU)										
Surface	42.2 (2.9), max=92		2.2 - 11.5	6.2 (0.8)	33.1 (9.34)	63.19 (24.1)	27.43 (2.16)	46.5 (45.1)	79.75 (2.36)	75.0 (6.6)
Bottom				5	13	34		38		73
TSS (mg/l)										
Bottom	102.2 (7.4), max=222			12	23	38		72		91

[a] Turbulence and bottom hazards prevented measurement
[b] velocity measurement at 0.2 depth

Lower Columbia River sturgeon also spawn in a confined reach, 12 km downstream of Bonneville Dam, with similar velocities (average 1.4 m/s), substrates (boulder 70%, cobble 23%), and temperatures (average 14.0 ^{o}C) as the Fraser River population (Table 3.2). Recently, a second spawning location was identified for the lower Columbia population in a major tributary, the Willamette River, Oregon (Chapman and Jones, 2010).

The following section summarizes the suitability of habitat index sites in the upper Columbia River as compared to habitat conditions found in White Sturgeon populations with good to excellent recruitment (i.e., Fraser and lower Columbia Rivers; Coutant 2004). In the only reporting of White Sturgeon spawning in an unregulated river (i.e., Fraser River), five of six spawning sites were in side channels of the meandering reach and one in the main channel of the confined reach (Perrin et al. 2003).

Meandering Reach (Golden to Donald): The meandering reach of the upper Columbia River offered the greatest diversity of habitats including eddies, sloughs, side channels, and braided channels with potentially suitable habitats for both spawning and early life stages (Figure 3.8). Upstream of Golden, the low velocities and fine substrates in comparison to the Fraser and lower Columbia River observations suggest that the area may be unsuitable to support a spawning population of White Sturgeon (Prince 2012).

Mean depths and velocities from Golden to Donald were within the range of values reported for spawning areas in the lower Columbia and Fraser Rivers (Table 3.2). Mean (SE) depths ranged from 4.88 (1.90) m at Golden to 2.8 (1.75) m downstream of the Kicking Horse River (i.e., Golden golf course). In the meandering reach of the Fraser River, eggs were most commonly found at water depths of 3.0 m with 100% of eggs being collected from side channels (Perrin et al., 2003). Maximum recorded depth in the 2012 survey was 8.4 m at Golden (Transect 1, Appendix A) though greater depths are available (15 m depth, Prince 2011). Deeper habitats may provide important adult holding and staging areas; however, given the high turbidity of the river, deeper holding areas may not be an important factor. To explain the observations of shallow spawning depths in the Fraser River (average = 3.4 m, range 1.5-5.0 m) compared with average spawning depths (6.0 m, range 4-23 m) in the low turbidity Columbia River, Perrin et al. (2003) hypothesized that there may be an inverse relationship between spawning depth and turbidity. Before hydroelectric development, rivers such as the Columbia and Kootenay would have had seasonally high concentrations of suspended sediment during the sturgeon spawning period allowing habitats of relatively shallow depth to become suitable for spawning (i.e., turbidity providing cover).

Bottom velocity measurements were limited due to turbulence and bottom hazards. Thus, bottom velocity data are skewed to locations where equipment was not at risk (i.e., low flow). Near bottom measurements (0.8 depth off the bottom) were possible at all sites and offer a better characterisation of site conditions for comparison. Near-bottom velocities at egg collection sites in the meandering reach of the Fraser River ranged from 1.3 to 2.2 m/s and averaged 1.9 m/s (Perrin et al., 2003). Velocities within this range were measured at every site in the Upper Columbia River (Table 3.2). The maximum near bottom velocity at each site measured: 2.08 m/s (Golden-Transect 4), 2.12 m/s (Kicking Horse-Transect 5), 1.39 m/s (Moberly main channel-Transect 1), 1.45 m/s (Moberly side channel-Transect 1), and 2.12 m/s (Blaeberry-Transect 1). For transect locations, refer to Appendix B.

Channel substrate in the meandering reach of the upper Columbia River was heterogeneous, and all size classes of sediment were represented with gravel, sand, and cobble being dominant (Table 3.2). Downstream of the Kicking Horse, the river channel widens and splits into several smaller channels. While sediment input (TSS) and deposition increases downstream of the Kicking Horse (Table 3.2), it is important to note that substrate is maintained in areas with flow. For example, at Site 5 Transect 5, measurements at the right bank (RB) and thelweg showed predominately gravels (10% cobble:60% gravel:30% sand) and flows of 1.28 m/s compared to the left bank (LB) which was dominated by sand (20% gravel:80% sand) and flows of 1.12 m/s (Appendix A). In the meandering reach of the Fraser River, dominant substrates at spawning sites were gravel/cobble (68%:27%) and gravel/sand (60%:33%) (Perrin et al., 2003).

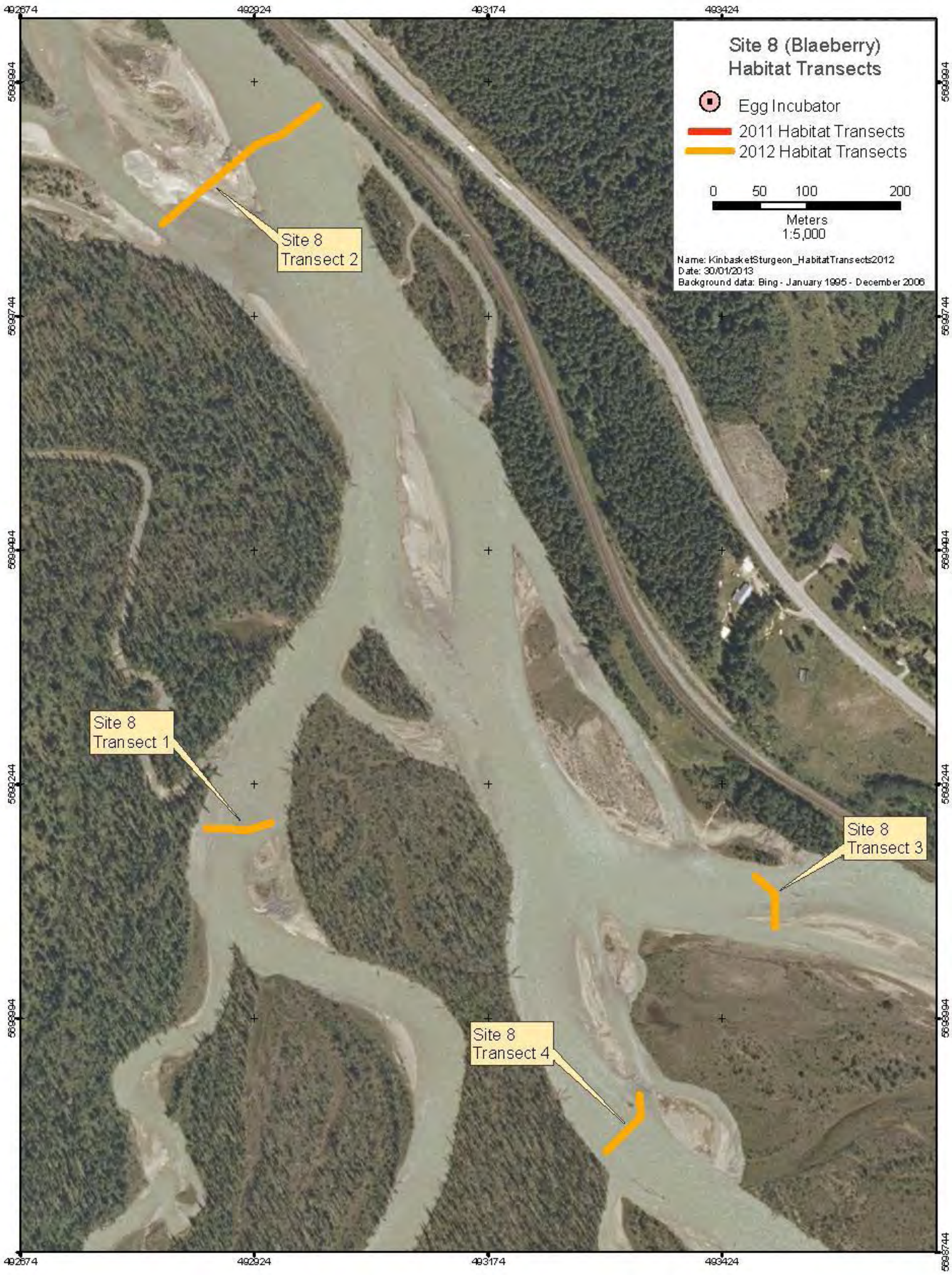

Figure 3.8 Meandering reach of the upper Columbia River at Blaeberry (Site 8). The overview shows transect locations in order from upstream (Transect 4) to downstream (Transect 2). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at 3-4 locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Turbidity was low (range = 5 to 8 NTU's) at Golden airport before two major tributaries; the Kicking Horse (1 km d/s), and Blaeberry Rivers (12 km d/s) enter the Columbia increasing flows, turbidity and providing zones of hydraulic complexity within the reach (Table 3.2). In the Fraser River, Perrin et al. (2003) found sturgeon spawning at turbidity levels of 92 NTU and TSS concentrations of 222 mg/L, with the average being 42 NTU and 102 mg/L (Table 3.2). Turbidity did not differ significantly among main and side channels in the Fraser River (Perrin et al., 2003). Drifting/dispersing larvae would have protection from visual predators by the turbidity of the upper Columbia River which ranged from an average of 33.1 NTU's below the Kicking Horse River to an average of 63.19 NTU's in the Moberly side channel (Table 3.2).

Confined Reach (Donald to Redgrave): The confined reach also offered suitable spawning and free embryo hiding habitats in comparison to confined reaches in the Fraser and lower Columbia rivers (Table 3.2). Downstream of Donald B.C., the Columbia River becomes confined and enters a narrow bedrock canyon. Two sites were sampled downstream of this canyon in an area known as Redgrave (Figure 3.9). Sampling was not possible in areas upstream of the canyon during this program due to 1) bridge construction which prevented river access at Donald and 2) extremely hazardous navigation through the canyon during peak discharge. However, this habitat was sampled during previous sturgeon investigations (CLBMON-19) and was described as having moderate velocity (1.67 m/s), depths of 3-8 m, and gravel/cobble substrates (Prince 2011).

Downstream of the canyon, the river was characterized by high velocity and turbulent flow. Two sites, upper and lower Redgrave, were identified by their positions relative to Redgrave Rapids, a major feature in this reach. Near bottom velocities in upper Redgrave (i.e., upstream of the rapids) averaged 2.15 m/s and ranged from 0.39 m/s in an eddy to 3.15 m/s (Transect 2 Figure 3.9, Appendix A). Suitable spawning depths (mean 3.04 m, range 2.9 to 4.5 m) and substrates were available (boulder 53%, cobble 28%) with finer materials accumulating in areas of reduced velocity (e.g., eddies, Appendix A). Similarly, lower Redgrave (i.e., Site 4 downstream of the rapids), had a mean (SE) near bottom velocity of 1.6 (1.0) m/s (range 0.21 to 3.06 m/s), a mean (SE) depth of 6.45 (2.6) m, and boulder (22%)/sand (18%) substrates (Table 3.2, Appendix A). Turbidity ranged from 65 to 88 NTU's and total suspended sediments (TSS) measured 91 mg/L (Table 3.2) These values reflect the sediment input of the Kicking Horse and Blaeberry Rivers combined with the increasing flows compared with 12 mg/L at the Golden Airport site. The average measurements of depth (3.73-6.45 m), velocity (1.6-2.2 m/s), and substrate (boulder/cobble) in the confined reach of the upper Columbia River are similar to conditions reported for sturgeon spawning habitats (i.e., newly spawned egg locations) in the confined reaches in the Fraser (depth=4.0 m, velocity=2.1 m/s, boulder/cobble/gravel substrates) and lower Columbia Rivers (depth=6.0 m, velocity=1.4-2.1 m/s, boulder/cobble substrates).

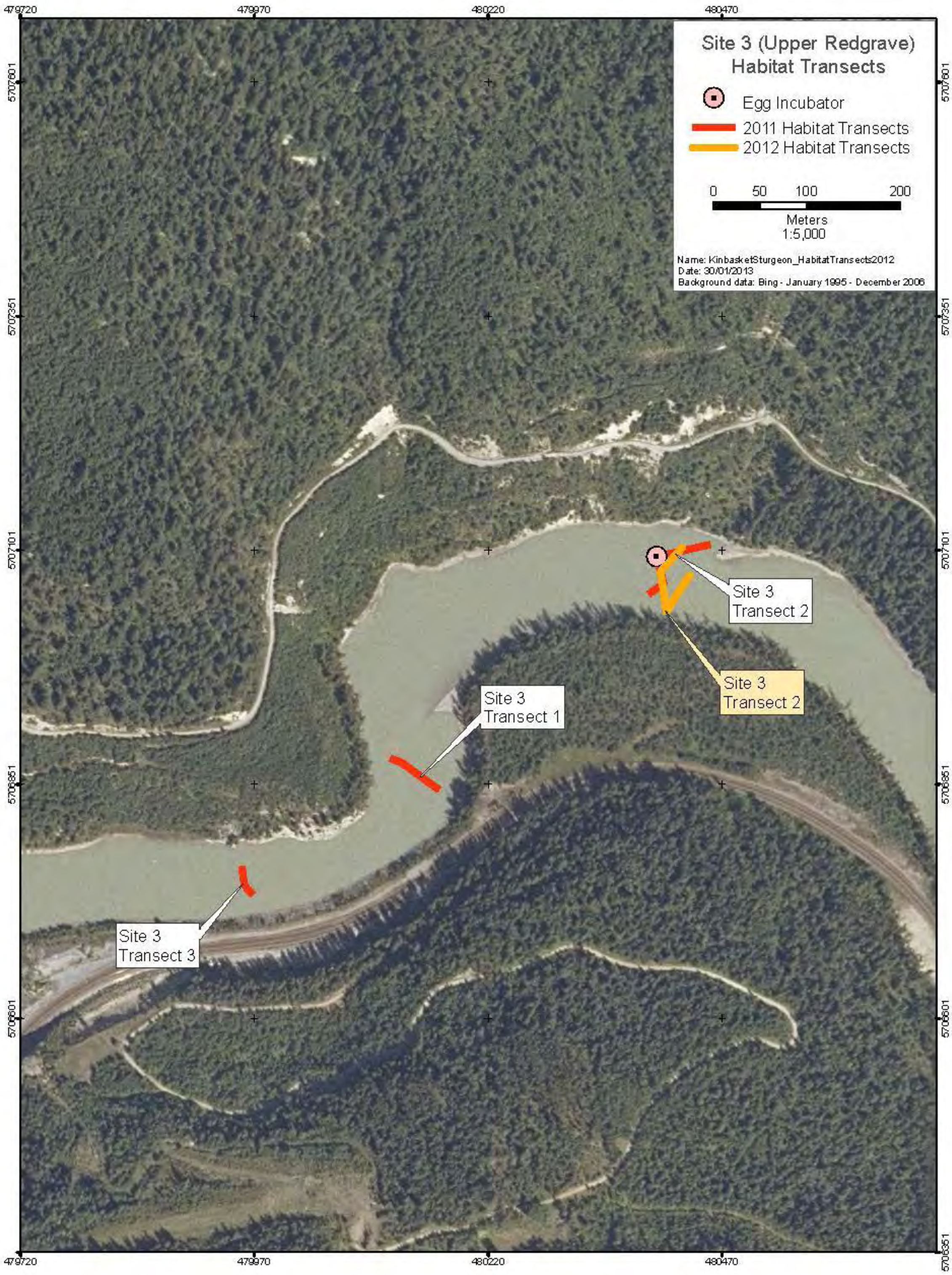

Figure 3.9 Habitat assessment Site 3 at Redgrave rapids (immediately downstream of the canyon). The overview shows transect locations in order from upstream (transect 2) to downstream (transect 3). Within each transect, measurements of depth, velocity, substrate and turbidity was taken at 3-4 locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Freshly deposited and/or scoured bed materials appear critical for egg survival and free embryo hiding habitats. Hatchling free embryos (Day 8, Conte et al., 1988, Prince 2012) are photonegative and hide under cover at a spawning site (Kynard et al., 2010, Crossman and Hildebrand 2012, McAdam 2011). In laboratory experiments, Fraser, Kootenai and Nechako River White Sturgeon embryos show a preference for small gravel substrates for hiding (1.2-2.2 cm diameter Bennett et al. 2007, 3-12 cm diameter Kynard et al. 2010, 1.2-1.9 cm diameter, McAdam 2011). In the absence of the smallest interstitial spaces, predation increased (McAdam 2011); however, the high turbidity levels in an unimpounded river during freshet may mitigate predation by impeding predator's ability to locate prey through olfactory interference or visual detection. The duration of the retention period at the spawning ground for fish species with a planktonic stage in the early part of their life history may be explained in terms of the mesoscale water movements that transport the larvae. If predation risk is high (due to dark body color for example), the developing yolk-sac embryos are not transported within the water column and the early initiation of active feeding and the ability to avoid predators are favoured (Nishimura and Hoshino 2009). The developmental stage where White Sturgeon external feeding usually begins approximately occurs at 232 ATU's (Conte et al. 1988) or 13 days after fertilization under the upper Columbia River thermal regime (Section 3.2.1 Diet and Prey Availability).

The approximately 40 km of Columbia River from Golden to Redgrave rapids offers a suitable combination of temperature, depth, substrate and velocity to support a spawning population of Columbia River White Sturgeon and provide free embryo hiding habitats. Though sediment deposition is a mortality factor for White Sturgeon embryos and high suspended sediment levels were measured in the upper Columbia River, there are sufficient flows from Golden downstream to Redgrave during the spawning and incubation periods to scour bed materials.

3.1.4. Contaminant Analysis

Introduction of contaminants in the Columbia River has been implicated as a possible cause of poor reproductive success for White Sturgeon (Gregory and Long 2008). The adhesiveness and permeability of White Sturgeon eggs following fertilization increases their susceptibility to contaminants associated with water, sediment and organic matter (Kruse and Scarnecchia, 2002a). Metals of interest were antimony, cadmium, chromium, copper, lead, mercury, nickel, tin, uranium, and zinc (Kruse and Webb 2006). In addition, measurements of organochlorine compounds (DDE and PCB Aroclor 1260) were recommended (Kruse and Webb 2006). Arsenic and manganese were also of interest in sturgeon populations as these pollutants may induce melano-macrophage activity (Kruse and Scarnecchia 2002b). A complete list of contaminants measured in the sampling region is given in Appendix C.

Arsenic is a teratogen and a carcinogen and has been reported to reduce growth and survival in fish (Kruse and Webb 2006). While its effects on early development on sturgeon are unknown, higher temperatures (15^{o}C vs. 5^{o}C) have been shown to reduce its toxicity response in rainbow trout (McGeachy and Dixon 1990). High levels of arsenic were detected in the sediment samples near Golden in both 2011 and 2012 (Table 3.3, 2011 level = 15.65 Prince 2012). The arsenic level at Site 5 (Kicking Horse) was above the guideline (7.42) in one sample and below the guideline (5.68) in the replicate sample. Sediment samples (n=2) from a single site in the Redgrave reach exceeded the guideline this year; however, levels were below guidelines in all samples collected last year (n=4 from two sites, Prince 2012). Thus, it appears that arsenic levels are at or below the guideline for all locations except Golden.

Nickel has been detected in very high concentrations in hatchery produced upper Columbia sturgeon and may reflect maternal transfer (Kruse and Webb 2006). Nickel levels exceeded the lowest effect guideline for sediments at Golden and Redgrave in both years of sampling (Table 3.3, Prince 2012).

River bottom sediments are believed to be a significant route for uptake of metals in White Sturgeon compared to water and suspended solids (Kruse and Scarnecchia 2002a). In water samples collected near bottom, lead levels were above the provincial guidelines for the protection of aquatic life at all sample locations in both 2011 and 2012 (Table 3.3). The lethality of lead levels is unclear as the criteria are form dependent and the laboratory results did not specify. Lead may also have a maternal effect as it was detected in very high concentrations in hatchery produced juvenile sturgeon (Kruse and Webb 2006).

Additional information on the lethality levels of arsenic, nickel, and lead are required to fully address the potential risks to early life stages for this species in the upper Columbia River as these metals were detected at concentrations that exceed the provincial guidelines for the protection of aquatic life (Table 3.3).

Table 3.3 Summary of contaminant analyses for habitats in the upper Columbia River, 2011. Concentrations are reported as micrograms/litre and are averaged (n=2) for each sample location. Values in red exceed BC provincial guidelines for freshwater aquatic life (Nagpal et al. 2006, 2001).

Sample Type	Parameter	BC Guideline for aquatic life	Golden (Site 2)	Kicking Horse (Site 5)	Moberly Side Channel (Site6)	Blaeberry (Site 8)	Lower Redgrave (Site 4)
Soil	Organochlorines (PCB's)	0.02	<0.03	<0.03	<0.03	<0.03	<0.03
	Antimony	n/a	0.32	0.23	0.195	0.13	0.275
	Arsenic	5.9	9.135	6.55	5.35	2.45	6.56
	Cadmium	0.6	0.104	0.155	0.21	0.1205	0.2795
	Chromium	37.3	16.3	13.35	12.55	12.35	14.65
	Copper	35.7	7.26	11.25	10.4	9.405	19.75
	Lead	35	11.15	17.5	21.9	9.415	25.45
	Maganese	460	303	435	450	434.5	538.5
	Mercury	0.17	<0.05	<0.05	<0.05	<0.05	<0.05
	Nickel[1]	16-75	19.25	17.85	15.65	15.5	19.45
	Tin	n/a	0.135	<0.10	0.105	0.37	0.225
	Uranium	n/a	0.656	0.5075	0.582	0.397	0.7525
	Zinc	123	44.1	61.9	75.2	40.2	65.2
Water	Total Hardness		81.3	98.85	100.1	106	154
	TSS (mg/L)		12.8	22.45	36.9	69	87.55
	turbidity		5.11	12.55	32.55	36.8	69.3
	Organochlorines (PCB's)	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Antimony	20	<0.50	<0.50	<0.50	<0.50	<0.50
	Arsenic	5	0.905	1.125	0.7	0.97	1.045
	Cadmium[2]	0.02-0.04	0.01	<0.01	0.0165	0.0195	0.0315
	Chromium	1	<1.0	<1.0	<1.0	1.5	2.15
	Copper	2	0.935	1.665	1.135	2.165	2.545
	Lead[3]	0.4	0.615	1.54	1.12	1.58	2.445
	Maganese	800	24.8	43.05	25.2	44	77.55
	Mercury	0.02	<0.05	<0.05	<0.05	<0.05	<0.05
	Nickel[2]	25	<1.0	1.6	<1.0	1.6	2.3
	Tin	0.4	<5.0	<5.0	<5.0	<5.0	<5.0
	Uranium	300	0.415	0.345	0.33	0.41	0.405
	Zinc[2]	33	<5.0	<5.0	<5.0	5.9	9.4

[1] lowest (16ug/L) to severe(75ug/L) effect level

[2] guideline is based on an total hardness: 0.02 @ 60 mg/L, 0.03 @ 90 mg/l and 0.04 @ 120 mg/L

[3] lethality unclear as criteria are form dependant and lab did not specify

Levels of chromium and copper were slightly above recommended guidelines at Redgrave for the second year of sampling (Table 3.2, Prince 2012). The measurement error for chromium was reported at 1.0 micrograms/litre and 0.20 micrograms/litre for copper. Chromium and copper accumulate in the eggs of ripe females (Kruse and Webb 2006) and while copper has been correlated with embryo mortality in White Sturgeon, the mortality rate was “not excessive” (Kruse and Scarnecchia 2002a). In a recent experiment, Vardy et al. (2011) found no difference in the hatching success of White Sturgeon eggs with increasing concentrations of copper, cadmium and zinc. In addition, Vardy et al. (2011) determined the chronic lethal concentrations at which 20% mortality occurred in White Sturgeon larvae (19d post hatch) and juveniles (58d post hatch): cadmium (1.5 µg/L), copper (5.5 µg/L) and zinc (112 µg/L). Thus, the dissolved levels of chromium and copper detected at Redgrave, while above provincial guidelines, appear to be within reasonably “safe” limits for the early life stages of White Sturgeon.

Unlike the lower Kootenai (Kruse and Webb 2002b) and impounded sections of the Lower Columbia River (Gundersen et al., 2008), the upper Columbia River appears free of organochlorines which adversely affect the growth and reproductive physiology of sturgeon (Kruse and Scarnecchia 2002b, Feist et al. 2005, Gundersen et al. 2008, Palumbo et al. 2009) and are believed to accumulate behind dams over time (Feist et al. 2005). With the possible exception of the sediment arsenic at Golden, the region also appears free of any metal contaminants that would impede the hatching and early development of White Sturgeon eggs and larvae. Thus, from a toxicological perspective, the upper Columbia River has water and sediment conditions suitable for the reproductive success of White Sturgeon.

3.1.5. Egg Survival

Egg plate arrays (six plates/array) were placed in six locations in the upper Columbia River: Golden, Kicking Horse, Moberly side channel, Blaeberry, Upper Redgrave, and Lower Redgrave (Table A2, Appendix A). Eggs were fertilized at 08:00 MST on July 18, deployed in the Columbia River from 17:00 hrs to 20:00 hrs and retrieved on July 24 2012. Hatching usually occurs at 6.5 - 8 days at 15°C (97.5 to 120 ATUs; Conte et al. 1988); however, there was no survival to hatch at any site in 2012. For reasons that remain unclear, there was 0% fertilization of the eggs provided for the egg plate work, both in the hatchery and in the field trial (Ron Ek, Kootenay Sturgeon Manager, pers. comm.,July 24 2012).

In 2011, survival rates for White Sturgeon eggs placed *in situ* at four locations in the Upper Columbia River were highest at Redgrave (36-73%) and lowest at Golden (1-5%) (Table 3.5). The low survival at Golden was attributed to the effects of suspended sediments (sand) and deployment method as the eggs appeared to have been fractured open (Prince 2012). Due to high velocities and debris during freshet, the egg plate array at Golden was at an acute angle and subject to direct flow (Prince 2012). Under normal conditions, spawned eggs would be protected from suspended sediment as they settle and adhere to substrates that deflect flow (Prince 2012). In upper and lower Redgrave, boulder substrates were dominant (53-22%, Table 3.2), and survival rates (Upper Redgrave mean= 51.2% ± 10.7 (SD), range 36-64%; Lower Redgrave mean= 63.0% ± 10.1 (SD), range 45-73%) were comparable to those reported elsewhere in the Columbia River (laboratory results for warm treatment (15°C) = 51.5-81.5% survival, Parsley 2010; *in situ* results at Waneta (14°C) mean= 66% ±17.3 (SD), range 50-92%, Golder 2010). Given the optimal temperature regime (14-16 °C) of the upper Columbia River for spawning and embryo development and the sheltering effect of substrates, egg survival is expected to be higher if eggs were deposited by broadcast spawning adults.

3.2. Larval and Juvenile Rearing Habitats

In the lower Columbia River, White Sturgeon larvae (day 13-65, n=131) are transported passively by river currents from spawning areas to deeper habitats (bimodal: 5m and 16m) with low velocities (mean = 1.6 m/s range 0.70-2.70 m/s) and sand substrates (Parsley et al. 1993). The narrow depth modes at 5 and 16m reflect the transport between embryo hiding areas and young-of-the-year (juvenile) habitats as the larvae mature (Parsley et al. 1993). In contrast, the depth distribution of larvae in lower Columbia River impoundments (n=215) is widely distributed around a mean of 15m (range 4-58 m; Parsley et al. 1993). In the Fraser River, larvae (n=101) were found at average temperatures of 14.5^{o}C, depths of 2.7 m (range 0.5 to 6.5 m), velocities of 1.0 m/s (range 0.5 to 1.8 m/s) and over substrates of gravel and sand (Perrin et al. 2003). Though several sites were sampled in the main Fraser River channel, larvae were collected only in the side channels of the meandering reach (Perrin et al. 2003). Larvae were collected in significantly lower velocities than eggs when depth was included as a covariate (Perrin et al, 2003). Because fluvial processes and channel morphology are unaltered by river engineering in the upper Columbia, there is an abundance of eddy and side channel habitat dominated by sand and silt substrates downstream of Golden and a diversity of hydraulic conditions (Appendix A). It is this diversity of moderate velocity gravel spawning beds with adjacent slower velocity depositional areas (0.5-1.5 m/s, Perrin et al., 2003) that offers suitable larval and juvenile habitats within the upper Columbia River, particularly the meandering reach from Golden to Donald (Table 3.2). Even in confined reaches of the Fraser River, larval collection sites were never turbulent and flows averaged 1.6 m/s (Perrin et al., 2003).

Hatchling free embryos show negative phototaxis and hide under cover at a spawning site while late embryos and larvae (Day 13) prefer white or bright substrate (Kynard et al. 2010). Larval populations from the Kootenai, Columbia and Sacramento Rivers have a common light grey body colour, which is believed to be an adaptation to hide from predators (Kynard et al. 2010). The glacial fines suspended in the upper Columbia River result in a white bottom and should prove beneficial with respect to the crypsis of white sturgeon juveniles (Figure 3.10).

Figure 3.10 Columbia River at Redgrave (Site 3 Transect 1) showing light, cobble substrate. Maximum depth measured 11 m, near bottom velocities ranged from 1.06 to 3.10 m/s, substrate was 49% boulder, 19% cobble, 13% gravel, 5% sand and bottom turbidity averaged 126 NTU. Egg survival was 51.2% (range 36-64%).

White Sturgeon larvae and juveniles do not use substrate cover (Gadomski and Parsley 2005, Young and Scarnecchia 2005) and are therefore particularly susceptible to predation in rivers lacking turbidity, a characteristic typical of regulated systems. Based on laboratory work, it is believed that predation may contribute significantly to mortality of White Sturgeon larvae and juveniles in the wild (Gadomski and Parsley 2005). With turbidity averaging 47.1 NTU's and TSS 47.2 mg/L, (compared to 2-11 NTUs in the lower Columbia River; Table 3.2), the upper Columbia River downstream of Golden should offer protection to dispersing sturgeon.

As sturgeon mature, they seek out more open habitats. In the lower Columbia River, young-of-the-year (20 - 321 mm TL) and juvenile White Sturgeon (Day 66) are found at depths of 2 to 40 m (mean 16 m), at mean water column velocities of 1.1 m/s and less, and over substrates of hard clay, mud, silt, and sand (majority over sand) (Parsley et al. 1993). In the Fraser River, juvenile sturgeon (age 1-12 yrs) were most abundant in slough and backwater eddy areas that had maximum depths > 5 m, slow currents (< 0.05 m/s) with variable flow direction, summer temperatures exceeding that of the mainstem by 5°C, and high turbidity (Lane and Rosenau, 1993). These conditions are found throughout the upper Columbia River with increasing depths, velocities, and courser substrates as the river flows downstream to Kinbasket Reservoir. Juveniles hatched near Golden would find suitable hiding habitats in the freshly deposited gravel/sand substrates that characterize the meandering reach, suitable low velocity larval habitats and early juvenile rearing habitats in the high turbidity side channels, and greater depths in the confined reach as juveniles disperse downstream. Older juveniles may prefer the deeper habitat of Kinbasket Reservoir where water temperatures may reach 18°C and there is an abundance of silt and sand substrates (Prince 2009), where they can feed efficiently using their ventral barbells and protrusible mouths to suck prey from the substrate (Muir et al., 2000).

3.2.1. Diet and Prey Availability

A possible cause for recruitment failure in White Sturgeon may be a lack of suitable prey availability at the onset of exogenous feeding (Muir et al., 2000). The developmental stage where external feeding usually begins occurs at 232 ATU's in hatchery-reared White Sturgeon (Conte et al. 1988) or 13 D post fertilization; however, in field studies, White Sturgeon larvae have been reported feeding as early as Day 8 (Muir et al. 2000). If prey abundance was relatively high, the early initiation of exogenous feeding associated with small egg size would result in an extended food acquisition period (Nishimura and Hoshino 2009).

In the lower Columbia River, first feeding White Sturgeon (Day 8, n=64) consumed (%= frequency of occurrence) *Corophium spp*. (amphipods=68%), Diptera pupae and larvae (primarily chironomids=52%), copepods (Cyclopoida=30%), and Ceratopogonidae larvae (22%, Muir et al. 2000). The early summer timing of sturgeon larval development coincides with the presence of juvenile invertebrates in the size range useable by larvae (Muir et al., 2000). The importance of larger invertebrates (e.g., Ephemeroptera, Plecoptera and Trichoptera) and fish in sturgeon diet increases with fish size (Muir et al., 2000).

Samples from sites in the upper Columbia indicated the presence of preferred invertebrate species at appropriate sizes for the onset of exogenous feeding (i.e., 125 µm) and subsequent developmental stages (i.e., 125 µm to 4mm; Table 3.4). Diptera spp. (63%) were the most abundant food type throughout the study area and were comprised primarily of Chironomidae, Simulidae, and Ceratopogonidae pupae and larvae (Appendix D). Crustaceans (*Cladocera, Daphinidae* and copepods) were the second most abundant food type in the samples collected and may be a suitable food type given the dominance of crustaceans in the lower Columbia (i.e., *Corophium spp.)*.

There is a favourable rearing period in both the river and reservoir with temperatures above 8°C (temperature at which consumption rate of 1% of body weight per day is reached, Ron Ek, sturgeon aquaculturist, *pers. comm.,* Freshwater Fisheries Society of BC, 2005) from April to October (Prince 2010), which should allow young of the year to reach a size large enough to survive their first winter.

With an estimated (all ages) 8.0 to 10.8 million kokanee in Kinbasket reservoir and a spawning escapement to the upper Columbia River of approximately one million (Westover 2003), the region has suitable prey availability at the onset of exogenous feeding and for young of the year and juvenile White Sturgeon.

Table 3.4. Relative abundance (%) of available food types from 125 µm to 4mm for the onset of exogenous feeding from samples collected in the upper Columbia River July 2012. Data for Golden and Redgrave are combined samples from July 2011 and 2012.

Order	**Golden (n=65)**	**Kicking Horse (n=280)**	**Moberly Main Channel[a] (n=134)**	**Moberly Side Channel (n=21)**	**Blaeberry (n=27)**	**Upper Redgrave[a] (n=99)**
Annelida (Class Hirudinea)			6.0			
Cladocera	27.7	0.5		33.3	85.2	
Copepoda (suborder)	3.1					
Diptera	23.1	95.0	54.5	14.3	11.1	35.4
Ephemeroptera	20.0	1.4		19.0		15.2
Gastropoda	3.1		2.2	9.5		2.0
Lepidoptera						1.0
Oligochaeta	7.7		29.9	4.8	3.7	25.3
Ostrocoda			6.0			
Plecoptera	13.8	2.5		9.5		19.2
Tripchoptera	1.5	1.0	1.5	9.5		2.0
tadpole			0.7			

[a] some fractions were subsampled due to high concentration of fines

4. Summary

This report summarizes the results of a study designed to assess the presence of suitable White Sturgeon spawning habitats, free embryo hiding habitats, larval, and juvenile under-yearling rearing habitats within Kinbasket Reservoir and the upper Columbia River (Management Question b, BC Hydro 2008). While conditions in the lower reaches of large tributaries to Kinbasket Reservoir (i.e., Sullivan and Wood Rivers) and in areas upstream of Golden (i.e., wetlands) were generally unfavourable (Prince 2012), the upper Columbia River from Golden to Redgrave appeared to contain suitable substrates and adequate physical parameters (e.g. temperature, flow, and turbidity).

The upper Columbia River has sufficient (maximum mean daily 1300 cms) and prolonged scouring flows (40-60 days mean daily discharge > 500 cms) that approach those in the Nechako (pre-dam) and Kootenai Rivers, providing freshly deposited and/or scoured substrates for free-embryo hiding habitats. The unique wetland habitat feature allows the upper Columbia to be significantly warmer than other large river tributaries in the Kinbasket region and temperatures are optimal for sturgeon egg incubation and rearing (14-16^{o}C, Wang et al., 1985).

The approximately 40 km of river from Golden (at the Kicking Horse River) downstream to Redgrave had mean depths (2.8-6.45 m), near bottom velocities (0.82 to 2.31 m/s), substrates (cobble/gravel and sand) and turbidities (mean 13-126 NTU) suitable to support a spawning population of White Sturgeon and their early life stages. Because fluvial processes and channel morphology are unaltered in the upper Columbia, there is an abundance of eddy and side channel habitats dominated by sand and silt substrates and a diversity of hydraulic conditions. It is this diversity of moderate velocity gravel spawning beds with immediately adjacent slower velocity depositional areas (0.5-1.5 m/s, Perrin et al., 2003) that offers suitable larval and juvenile habitats within the upper Columbia River, particularly the meandering reach from Golden to Donald. Furthermore, the upper Columbia River has suitable prey availability for the onset of exogenous feeding and older life stages of young of the year and juvenile White Sturgeon. Dispersing juveniles reared in the upper Columbia River would find suitable foraging, shelter and large fish populations downstream in Kinbasket Reservoir (Prince 2009). Thus, the upper Columbia River region appears to offer suitable habitats to support all life stages of White Sturgeon.

Unlike the lower Kootenai and impounded sections of the Lower Columbia River, the upper Columbia River was free of organochlorines, which adversely affect the growth and reproductive physiology of sturgeon. With the exception of sediment arsenic at Golden, the region also appears free of any metal contaminants that would impede the hatching and early development of White Sturgeon eggs and larvae. *In situ* egg survival rates at Redgrave (range 36-73%) were comparable to those reported elsewhere in field studies in the Columbia River.

There remains some uncertainty regarding egg survival in the meandering reach of the Columbia River as the incubation experiment was unsuccessful due to a lack of fertilization success at the hatchery. Though sediment deposition is a mortality factor for White Sturgeon embryos, eggs incubated in the meandering reach may not be impeded by the high suspended sediment given 1) egg survival rates in the confined reach of the upper Columbia (TSS=190 mg/l, Prince 2012) are similar to laboratory (Parsley 2010) and other *in situ* results (Golder 2010), 2) TSS levels of 222 mg/l measured at spawning and incubation sites in the Fraser River (Perrin et al. 2003), and 3) the high, sustained optimal flow and temperature regime of the river.

Habitat measurements in this program were focused on spawning and early life stage (embryos and larvae) requirements and will aid in the development of a conservation aquaculture protocol. Golden, downstream of the Kicking Horse River, should be considered as a possible release site since it is the furthest upstream point to offer sequential, suitable habitats for spawning and early life stages. As well as maximizing the availability of suitable habitats, Golden has significant logistical advantages and would allow for the implementation of alternate stocking strategies (e.g. larvae vs. juvenile). Further information is needed to address whether or not there are suitable juvenile (young-of-the-year) and sub adult habitats in the upper Columbia study area. These assessments would require additional habitat measurements in areas of reduced velocities and increased depths (e.g., eddy habitats and Kinbasket reservoir). Information on existing fish communities in the upper Columbia River is also lacking and necessary to identify potential risks (e.g., predation, parasites) of a conservation aquaculture stocking program.

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Appendix A

Transect Data

Table A1 Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Record #	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Distance from wetted width (m)	UTM Easting	(11N) Northing	Total Depth (m)	Velocity Method (Wading or 50 lb CW)	Bottom Rev	Bottom Time(s)	bottom m/s	0.8 Rev	0.8 Time(s)	0.8 m/s	0.2 Rev	0.2 Time(s)	0.2 m/s
2	Golden Airport	09-Jul-12	1	1	LB	21.95	501936	5681198	6.30	50	46	60	0.52	89	59.6	1.00	109	60	1.22
2	Golden Airport	09-Jul-12	2	1	LM	28.35	501943	5681201	6.80	50	stick			31	61	0.34	94	60	1.05
2	Golden Airport	09-Jul-12	3	1	Thalweg	54.86	501969	5681204	8.30	50	90	60	1.01	101	61	1.11	110	60	1.23
2	Golden Airport	09-Jul-12	4	1	RM	69.49	501984	5681202	8.40	50	66	60	0.74	76	60	0.85	95	60	1.06
	Average			**1**					**7.45**				**0.75**			**0.83**			**1.14**
2	Golden Airport	09-Jul-12	5	2	LB	22.86	501648	5681756	6.20	50	61	60	0.68	75	60	0.84	90	60	1.01
2	Golden Airport	09-Jul-12	6	2	LM	40.69	501664	5681765	5.30	50	54	60	0.60	62	60	0.69	82	60	0.92
2	Golden Airport	09-Jul-12	7	2	Thalweg	58.52	501678	5681777	6.10	50	64	60	0.72	68	60	0.76	90	60	1.01
2	Golden Airport	09-Jul-12	8	2	RB	81.84	501706	5681782	5.90	50	47	60	0.53	83	60	0.93	112	60	1.25
	Average			**2**					**5.88**				**0.63**			**0.80**			**1.04**
2	Golden Airport	09-Jul-12	9	3	LM	18.29	501231	5682648	3.10	50	70	32	1.46	137	60	1.53	131	52	1.69
2	Golden Airport	09-Jul-12	10	3	Thalweg	48.92	501250	5682662	3.20	50	130	60	1.45	140	60	1.56	100	34	1.97
2	Golden Airport	09-Jul-12	11	3	Thalweg	48.92	501250	5682662	3.20	50	130	60	1.45	140	60	1.56	125	43	1.95
2	Golden Airport	09-Jul-12	12	3	RM	81.38	501298	5682668	2.20	50	140	61	1.54	140	60	1.56	160	60	1.78
	Average			**3**					**2.93**				**1.48**			**1.55**			**1.85**
2	Golden Airport	09-Jul-12	13	4	LM	19.20	500960	5683048	3.90	50	50	48.5	0.69	30	48	0.42	70	60	0.78
2	Golden Airport	09-Jul-12	14	4	Thalweg	44.35	500980	5683055	4.30	50	155	60	1.73	190	61	2.08	220	61	2.41
2	Golden Airport	09-Jul-12	15	4	RM	59.44	501000	5683065	3.90	50	115	45	1.71	175	60	1.95	185	60	2.06
	Average			**4**					**4.03**				**1.38**			**1.49**			**1.75**
2	Golden Airport	09-Jul-12	16	5	LB	3.66	500727	5683620	2.70	50				35	60	0.39	35	60	0.39
2	Golden Airport	09-Jul-12	17	5	LM	27.43	500745	5683610	6.20	50				165	60	1.84	230	60	2.56
2	Golden Airport	09-Jul-12	18	5	Thalweg	43.89	500769	5683595	4.50	50				175	60	1.95	215	60	2.40
2	Golden Airport	09-Jul-12	19	5	RB	58.52	500785	5683608	2.30	50	130	60	1.45	145	60	1.62	125	60	1.39
	Average			**5**					**3.93**							**1.45**			**1.69**
2	**Mean (SD)**								**4.88 (1.9)**				**1.08 (0.5)**			**1.21 (0.6)**			**1.48 (0.6)**

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Substrate (%) Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other	Cover (%)	Surface Turbidity (NTU's)	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a] Temp (°C)	Cond (us)	DO mg/L	pH	Comments
2	Golden Airport	09-Jul-12	1	LB		10	50	30	10		0	8	N	N	N	18.0				
2	Golden Airport	09-Jul-12	1	LM				90	10			7	N	N	N	18.0				
2	Golden Airport	09-Jul-12	1	Thelweg				90	10			7	N	N	N	18.1	173	9.0	8.9	
2	Golden Airport	09-Jul-12	1	RM			10	80	10			7	N	N	N	18.0				
2	**Average**		**1**		**0**	**3**	**15**	**73**	**10**		**0**	**7**				**18.0**	**173**	**9.0**	**8.9**	
2	Golden Airport	09-Jul-12	2	LB				90	10			5	N	N	N	18.2				
2	Golden Airport	09-Jul-12	2	LM			10	70	20			6	N	N	N					
2	Golden Airport	09-Jul-12	2	Thalweg			20	60	20	SWD		5	N	N	N					
2	Golden Airport	09-Jul-12	2	RB		10	30	40	20	LWD	50	7	Y	N	N	18.3	174	7.8	7.9	
2	**Average**		**2**		**0**	**3**	**15**	**65**	**18**	**SWD**	**0**	**6**				**18.1**	**173**	**9.0**	**8.9**	
2	Golden Airport	09-Jul-12	3	LM	5	45	10	10			20	6	Y			18.0	173	8.2	8.0	
2	Golden Airport	09-Jul-12	3	Thalweg	5	65	20	10			20	6	N							
2	Golden Airport	09-Jul-12	3	Thalweg	5	65	20	10			20	6	N							
2	Golden Airport	09-Jul-12	3	RM	5	50	25	10			20	6	N							
2	**Average**		**3**		**5**	**56**	**19**	**10**	**0**		**20**	**6**				**18.0**	**173**	**8.2**	**8.0**	
2	Golden Airport	09-Jul-12	4	LM		5	40	55				6	Y			18.0	173	8.0	8.2	
2	Golden Airport	09-Jul-12	4	Thalweg		30	50	20				6	N							
2	Golden Airport	09-Jul-12	4	RM		15	70	15				5	N							
2	**Average**		**4**		**0**	**17**	**53**	**30**	**0**	**SWD**		**6**				**18.0**	**173**	**8.0**	**8.2**	
2	Golden Airport	09-Jul-12	5	LB	100							8	Y	N	N	18.0	173	8.4	8.0	
2	Golden Airport	09-Jul-12	5	LM	20	20	20	20	40				N	N	N					
2	Golden Airport	09-Jul-12	5	Thalweg			10	60	30			6	N	N	N					
2	Golden Airport	09-Jul-12	5	RB				20	80			6	N	N	Y					
2	**Average**		**5**		**30**	**5**	**8**	**25**	**38**	**SWD**		**7**				**18.0**	**173**	**8.2**	**8.1**	
2	**Summary**				**7**	**17**	**22**	**41**	**13**			**6.2 (0.8)**				**18.0**	**173**	**8.5**	**8.4**	

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Record #	Transect #	Channel Location	Distance from wetted width	UTM	(11N)	Total Depth (m)	Velocity									
					(look d/s)	(m)	Easting	Northing		Method	Bottom			0.8			0.2		
					(LB/RB, LM/RM, Thalweg)					(Wading or 50 lb CW)	Rev	Time(s)	bottom m/s	Rev	Time(s)	0.8 m/s	Rev	Time(s)	0.2 m/s
3	Upper Redgrave	11-Jul-12	20	2	RB	18.29	480428	5707104	4.50	50	EDDY	EDDY		210	60	2.34	250	57	2.93
3	Upper Redgrave	11-Jul-12	21	2	Thalweg	58.52	480405	5707078	4.30	50				250	53	3.15	250	48	3.48
3	Upper Redgrave	11-Jul-12	22	2	LB	93.27	480411	5707036	2.90	50				245	60	2.73	255	57	2.99
3	Upper Redgrave	11-Jul-12	23	2	Eddy		480136	5707074	3.20	50				35	60	0.39	50	60	0.56
3	**Mean (SD)**								**3.73(0.8)**							**2.15 (1.2)**			**2.49 (1.3)**
4	Lower Redgrave	11-Jul-12	24	1	RB	18.75	478778	5706423	7.60	50	35	73	0.32				90	56	1.08
4	Lower Redgrave	11-Jul-12	25	1	Thalweg	57.61	478751	5706397	8.70	50				250.00	60	2.79	250	55.3	3.02
4	Lower Redgrave	11-Jul-12	26	1	LB	75.44	478873	5706394	5.30	50				275.00	60	3.06	250	56.7	2.95
	Average			**1**					**7.20**				**0.32**			**2.93**			**2.35**
4	Lower Redgrave	11-Jul-12	27	2	RB	13.72	477871	5706280	6.30	50				185	60	2.06	225.00	60	2.51
4	Lower Redgrave	11-Jul-12	28	2	Thalweg	39.32	477880	5706258	7.50	50				235	60	2.62	235.00	61	2.58
4	Lower Redgrave	11-Jul-12	29	2	LB	59.44	477886	5706233	5.10	50				165	60	1.84	145.00	60	1.62
	Average			**2**					**6.30**							**2.17**			**2.23**
4	Lower Redgrave	11-Jul-12	30	3	RB	74.07	477487	5706608	1.00	50	3	80	0.03						
4	Lower Redgrave	11-Jul-12	31	3	RM	121.62	477451	5706572	6.00	50	18	60	0.20	37	60	0.42	32	60	0.36
4	Lower Redgrave	11-Jul-12	32	3	Thalweg	169.16	477436	5706523	9.60	50				145	60	1.62	137	60	1.53
4	Lower Redgrave	11-Jul-12	33	3	LB	210.31	477402	5706520	8.50	50				160	60	1.78	160	60	1.78
	Average			**3**					**6.28**				**0.12**			**1.27**			**1.22**
4	Lower Redgrave	11-Jul-12	34	4	RB	13.72	477296	5706892	7.90	50				20	60	0.23	30	60	0.34
4	Lower Redgrave	11-Jul-12	35	4	RM	74.52	477248	5706842	8.50	50				70	60	0.78	70	60	0.78
4	Lower Redgrave	11-Jul-12	36	4	LM	92.35	477233	5706843	6.70	50				121	60	1.35	106	60	1.18
4	Lower Redgrave	11-Jul-12	37	4	LB	156.36	477134	5706824	1.60	50	11	60	0.13	19	60	0.21	16	60	0.18
	Average			**4**					**6.18**				**0.13**			**0.64**			**0.62**
4	**Mean (SD)**								**6.45 (2.6)**				**0.17 (0.1)**			**1.6 (1.0)**			**1.53 (1.0)**

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Substrate (%) Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other	Cover	Surface Turbidity (NTU's)	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a] Temp (°C)	Cond (us)	DO mg/L	pH	Comments
3	Upper Redgrave	11-Jul-12	T2	RB	40	40	20				flow	78	N	N	Y	14.3	185	9.5	8.5	Egg Incubatio Site
3	Upper Redgrave	11-Jul-12	T2	Thalweg	70	30						83	N	N	Y					
3	Upper Redgrave	11-Jul-12	T2	LB	50	30	20					80	N	N	Y					
3	Upper Redgrave	11-Jul-12	T2	Eddy		10	40	30	20			78	N	N	Y					
3	**Summary**				**53**	**28**	**27**	**30**	**20**			**79.75 (2.36)**				**14.3**	**185**	**9.5**	**8.5**	
4	Lower Redgrave	11-Jul-12	T1	RB	20	20	10	40	20		Eddy	88.0	N	N	N	14.6	185	10.0	8.2	
4	Lower Redgrave	11-Jul-12	T1	Thalweg	80	20					flow	74.0	N	N	N					
4	Lower Redgrave	11-Jul-12	T1	LB							flow	74.0	N	N	N					
4	**Average**		**T1**		**33**	**13**	**3**	**13**	**7**			**79**				**14.6**	**185**	**10.0**	**8.2**	
4	Lower Redgrave	11-Jul-12	T2	RB	80	20						78.0	N	N	N					
4	Lower Redgrave	11-Jul-12	T2	Thalweg	60	40						76.0	N	N	N					
4	Lower Redgrave	11-Jul-12	T2	LB	20	30	20	15	15	veg	Eddy	80.0	N	N	N	14.9	184	9.6	8.1	
4	**Average**		**2**		**53**	**30**	**7**	**5**	**5**			**78**				**14.9**	**184**	**9.6**	**8.1**	
4	Lower Redgrave	11-Jul-12	T3	RB				40	60	veg	Eddy	65.0	N	N	N	15.0	185	9.6	8.2	
4	Lower Redgrave	11-Jul-12	T3	RM							Eddy	81.0	Y	Y	N					
4	Lower Redgrave	11-Jul-12	T3	Thalweg									N	N	N					
4	Lower Redgrave	11-Jul-12	T3	LB								80.0	N	N	N					
4	**Average**		**T3**		**0**	**0**	**0**	**10**	**15**			**75**				**15.0**	**185**	**10**	**8**	
4	Lower Redgrave	11-Jul-12	T4	RB		10	40	30	20			73.0	N	N	N	15.1	185	9.3	8.3	
4	Lower Redgrave	11-Jul-12	T4	RM			30	60	10			73.0	N	N	N					
4	Lower Redgrave	11-Jul-12	T4	LM			20	40	40			68.0	N	N	N					
4	Lower Redgrave	11-Jul-12	T4	LB				40	60	veg		65.0	N	N	N					
4	**Average**		**T4**		**0**	**3**	**23**	**43**	**33**			**69.8**				**15.1**	**185**	**9.3**	**8.3**	
4	**Summary**				**21.7**	**11.5**	**8.1**	**17.7**	**14.8**			**75.0 (6.6)**				**14.9**	**185**	**9.6**	**8.2**	

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Record #	Transect #	Channel Location	Distance from wetted width	UTM	(11N)	Total Depth (m)	Velocity									
					(look d/s)	(m)	Easting	Northing		Method	Bottom			0.8			0.2		
					(LB/RB, LM/RM, Thalweg)					(Wading or 50 lb CW)	Rev	Time(s)	bottom m/s	Rev	Time(s)	0.8 m/s	Rev	Time(s)	0.2 m/s
5	Kicking Horse	13-Jul-12	38	1	LB	4.00	499334	5687880	2.00	W				14	64	0.15	20	60	0.23
5	Kicking Horse	13-Jul-12	39	1	LM	24.00	499365	5687900	3.10	W	100	62	1.08	95	60	1.06	100	51	1.31
5	Kicking Horse	13-Jul-12	40	1	Thalweg	70.00	499395	5687921	2.80	W							190	59	2.15
5	Kicking Horse	13-Jul-12	41	1	RM	111.00	499416	5687943	1.80	W							130	60	1.45
	Average			**1**					**2.43**				**1.08**			**0.61**			**1.29**
5	Kicking Horse	13-Jul-12	42	2	LB	14.50	499412	5687625	1.50	W							35	60	0.39
5	Kicking Horse	13-Jul-12	43	2	Thalweg	28.50	499429	5687633	1.80	W	55	32	1.15				180	60	2.01
5	Kicking Horse	13-Jul-12	44	2	**RB**	51.00	499448	5687629	1.80	W							70	60	0.78
	Average			**2**					**1.70**				**1.15**						**1.06**
5	Kicking Horse	13-Jul-12	45	3	LB	15.00	500091	5687531	2.50	W							120	60	1.34
5	Kicking Horse	13-Jul-12	46	3	Thalweg	36.00	500103	5687547	1.80	W							160	60	1.78
5	Kicking Horse	13-Jul-12	47	3	RB	55.00	500119	5687555	2.20	W							150	60	1.67
5	**Average**			**3**					**2.17**										**1.60**
5	Kicking Horse	13-Jul-12	48	4	RB	23.00	499185	5687884	2.20	W							11	62	0.12
5	Kicking Horse	13-Jul-12	49	4	Thalweg	10.00	499195	5687879	2.50	W							106	60	1.18
	Kicking Horse	13-Jul-12	50	4	LB	6.00	499194	5687874	1.80	W	77	60	0.86				107	60	1.19
5	**Average**			**4**									**0.86**						**0.83**
5	Kicking Horse	13-Jul-12	51	5	LB	10.00	498464	5688135	6.50	W				90	60	1.01	30	65	0.31
5	Kicking Horse	13-Jul-12	52	5	Thalweg	26.00	498470	5688153	7.70	W				190	60	2.12	190	60	2.12
5	Kicking Horse	13-Jul-12	53	5	RM	56.00	498480	5688173	2.80	W							180	60	2.01
	Average			5												**1.56**			**1.48**
5	**Mean (SD)**								**2.8 (1.75)**				**1.03 (0.15)**			**1.08 (0.8)**			**1.25 (0.7)**

Table A1 con't Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Transect #	Channel Location	Substrate (%)						Cover	Surface Turbidity	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a]				Comments
				(look d/s) (LB/RB, LM/RM, Thalweg)	Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other		(NTU's)				Temp (°C)	Cond (us)	DO mg/L	pH	
5	Kicking Horse	13-Jul-12	1	LB				50	50		Veg	150	N	N	N	17.5	165	8.1	8.7	Eddy on island point with tidbits
5	Kicking Horse	13-Jul-12	1	LM		20	60	20			LWD	23	Y	Y	Y					
5	Kicking Horse	13-Jul-12	1	Thalweg		30	40	30			LWD	34	N	N	N					
5	Kicking Horse	13-Jul-12	1	RM		40	40	20			LWD	34	N	N	N					
5	**Average**		**1**		**0**	**23**	**35**	**30**	**13**	**0**		**60**				**17.5**	**165**	**8.1**	**8.7**	
5	Kicking Horse	13-Jul-12	2	LB			80	20		SWD	Veg	16	Y	N	N	17.9	166	8.3	8.2	Veg side channel-lower turbidity, lots of cover
5	Kicking Horse	13-Jul-12	2	Thalweg		20	60	20		LWD	Veg	16	N	N	N					
5	Kicking Horse	13-Jul-12	2	RB		20	50	30		LWD	Veg	16	N	N	N					
5	**Average**		**2**		**0**	**13**	**63**	**23**				**16**				**17.9**	**166**	**8.3**	**8.2**	
5	Kicking Horse	13-Jul-12	3	LB			60	40		LWD	Veg	60	Y	N	N	14.3	179	10.0	8.3	Kicking Horse influenced flow
5	Kicking Horse	13-Jul-12	3	Thalweg		10	50	40					N	N	N					
5	Kicking Horse	13-Jul-12	3	RB		10	50	40				62	N	N	N					
5	**Average**		**3**		**0**	**8**	**56**	**36**	**0**	**0**		**61**				**14.3**	**179**	**10.0**	**8.3**	
5	Kicking Horse	13-Jul-12	4	RB					100	LWD	LWD	15	Y	N	N	18.1	166	8.0	8.2	Side channel + logjam + beaver house
5	Kicking Horse	13-Jul-12	4	Thalweg			80	20				14	N	N	N					
5	Kicking Horse	13-Jul-12	4	LB			50	50		Veg		14	N	N	N					
5	**Average**		**4**		**0**	**2**	**46**	**26**	**25**	**0**		**14**				**18.1**	**166**	**8.0**	**8.2**	
5	Kicking Horse	13-Jul-12	5	LB		20	60	20		LWD	LWD	15	Y	N	N	17.6	166	7.5	8.3	
5	Kicking Horse	13-Jul-12	5	Thalweg		60	10					14	N	N	N					
5	Kicking Horse	13-Jul-12	5	RM		40	60					14	N	N	N					
5	**Average**		**5**		**0**	**31**	**44**	**12**	**6**	**0**		**14**				**17.6**	**166**	**7.5**	**8.3**	
5	**Summary**				**0.0**	**15.4**	**48.9**	**25.4**	**8.8**	**0.0**		**33.2**				**17.1**	**168.4**	**8.4**	**8.4**	

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Record #	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalw eg)	Distance from wetted width (m)	UTM Easting	(11N) Northing	Total Depth (m)	Velocity Method (Wading or 50 lb CW)	Bottom Rev	Bottom Time(s)	bottom m/s	0.8 Rev	0.8 Time(s)	0.8 m/s	0.2 Rev	0.2 Time(s)	0.2 m/s
7	Moberley (main)	14-Jul-12	54	1	RB	10.60	496380	5693977	4.00	W							95	61	1.04
7	Moberley (main)	14-Jul-12	55	1	RM	37.00	496361	5693958	5.90	W							175	82	1.43
7	Moberley (main)	14-Jul-12	56	1	LM	71.00	496331	5693939	6.80	W				125	60	1.39	160	73	1.47
7	Moberley (main)	14-Jul-12	57	1	LB	104.00	496312	5693911	6.20	W							80	62	0.87
7	Moberley (main)	14-Jul-12	58	1	s/c	50.00	496262	5693916	2.70	W							25	63	0.27
	Average								**5.12**							**1.39**			**1.01**
7	Moberley (main)	14-Jul-12	59	2	RB	18.70	496700	5693611	4.90	W							125	60	1.39
7	Moberley (main)	14-Jul-12	60	2	Thalw eg	56.00	496646	5693598	5.20	W				120	60	1.34	135	60	1.51
7	Moberley (main)	14-Jul-12	61	2	LB	87.00	496661	5693552	5.50	W							90	60	1.01
7	Moberley (main)	14-Jul-12	62	2	s/c	50.00	496638	5693513	1.50	W							45	64	0.47
	Average			**2**					**4.28**							**1.34**			**1.09**
7	Moberley (main)	14-Jul-12	63	3	RB	16.70	497715	5693173	3.30	W	65	60	0.73	80	60	0.89	95	63	1.01
7	Moberley (main)	14-Jul-12	64	3	Thalw eg	40.00	497717	5693141	2.50	W							85	63	0.90
7	Moberley (main)	14-Jul-12	65	3	LB	63.90	497710	5693123	1.80	W							80	62	0.87
	Average			**3**					**2.53**							**0.89**			**0.93**
7	Moberley (main)	14-Jul-12	66	4	RB	20.00	497642	5692993	4.30	W							120	61	1.32
7	Moberley (main)	14-Jul-12	67	4	Thalw eg	44.70	497611	5692986	5.20	W	85	60	0.95	94	60	1.05	110	60	1.23
7	Moberley (main)	14-Jul-12	68	4	LB	69.10	497619	5692945	4.90	W							80	60	0.89
	Average			**4**					**4.80**							**1.05**			**1.15**
7	Moberley (main)	14-Jul-12	69	5	RB	22.00	498109	5692623	4.00	W				90	60	1.01	120	63	1.28
7	Moberley (main)	14-Jul-12	70	5	Thalw eg	35.00	498097	5692595	3.40	W							105	60	1.17
7	Moberley (main)	14-Jul-12	71	5	LB	105.00	498057	5692555	3.40	W							100	60	1.12
7	Moberley (main)	14-Jul-12	72	5	s/c	215.00	497945	5692504	4.90	W							90	60	1.01
	Average			**5**					**3.93**							**1.01**			**1.14**
5	**Mean (SD)**								**4.23 (1.5)**				**0.8 (0.2)**			**1.14 (0.2)**			**1.07 (0.3)**

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment

Site	Discription	Date	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Substrate (%) Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other	Cover	Surface Turbidity (NTU's)	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a] Temp (°C)	Cond (us)	DO mg/L	pH	Comments
7	Moberley (main)	14-Jul-12	1	RB								35	N	N	Y	15.5	181	8.5	8.3	Serber, above s/c outlet
7	Moberley (main)	14-Jul-12	1	RM								31								
7	Moberley (main)	14-Jul-12	1	LM			20	80		LWD		31								
7	Moberley (main)	14-Jul-12	1	LB				80	20			15								
7	Moberley (main)	14-Jul-12	1	s/c				80	20	LWD		17				17.4	173	7.7	8.2	Anchored off LWD jam for contrast
7	**Average**		**1**		**0.00**	**0.00**	**5.00**	**60.00**	**10.00**	**0.00**	**0.00**	**32.25**				**16.4**	**177**	**8.11**	**8.27**	
7	Moberley (main)	14-Jul-12	2	RB				50	50			36	N	N	N	15.4	180	8.6	8.2	Main x/s + outlet small s/c
7	Moberley (main)	14-Jul-12	2	Thalweg			40	60				27	N	N	N					
7	Moberley (main)	14-Jul-12	2	LB			15	15	70			20	N	N	Y					
7	Moberley (main)	14-Jul-12	2	s/c								8	N	N	N	17.9	178	7.3	8.3	Side channel outlet
7	**Average**		**2**		**0.00**	**0.00**	**13.75**	**31.25**	**30.00**	**0.00**	**0.00**	**22.68**				**16.6**	**179**	**7.95**	**8.26**	
7	Moberley (main)	14-Jul-12	3	RB				100				35	N	N	N	15.4	179	8.7	8.3	East Channel
7	Moberley (main)	14-Jul-12	3	Thalweg				100				36	N	N	N					
7	Moberley (main)	14-Jul-12	3	LB				100				36	N	N	N					
7	**Average**		**3**		**0.00**	**0.00**	**0.00**	**100.00**	**0.00**	**0.00**	**0.00**	**32**				**16.0**	**179**	**8.3**	**8.3**	
7	Moberley (main)	14-Jul-12	4	RB		20	50	30				26	N	N	N	16.4	174	8.4	8.2	West Channel
7	Moberley (main)	14-Jul-12	4	Thalweg			10	90				23	N	N	N					
7	Moberley (main)	14-Jul-12	4	LB								24	N	N	N					
7	**Average**		**4**		**0.00**	**6.67**	**20.00**	**40.00**	**0.00**	**0.00**	**0.00**	**24.00**				**16.2**	**177**	**8.3**	**8.2**	
7	Moberley (main)	14-Jul-12	5	RB		10	60	30				49	N	N	N	15.1	180	8.9	8.2	Main channel East Trans. Can. Hwy.
7	Moberley (main)	14-Jul-12	5	Thalweg			50	50				28	N	N	N					
7	Moberley (main)	14-Jul-12	5	LB			20	80				24	N	N	N					
7	Moberley (main)	14-Jul-12	5	s/c								22	N	N	N	17.0	170	8.1	8.3	Side channel west side
7	**Average**		**5**		**0.00**	**2.50**	**32.50**	**40.00**	**0.00**	**0.00**	**0.00**	**30.70**				**16.1**	**175**	**8.49**	**8.25**	
7	**Summary**				**0.0**	**1.8**	**14.3**	**54.3**	**8.0**	**0.0**	**0.0**	**28.4**				**16.3**	**177.3**	**8.2**	**8.3**	

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment

Site	Discription	Date	Record #	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Distance from wetted width (m)	UTM Easting	(11N) Northing	Total Depth (m)	Velocity Method (Wading or 50 lb CW)	Bottom Rev	Bottom Time(s)	bottom m/s	0.8 Rev	0.8 Time(s)	0.8 m/s	0.2 Rev	0.2 Time(s)	0.2 m/s
6	Moberley (side channel)	15-Jul-12	73	1	RB	6.60	498305	5692303	3.10	W							120	60	1.34
6	Moberley (side channel)	15-Jul-12	74	1	Thalweg	21.60	498286	5692313	4.00	W				130	60	1.45	130	60	1.45
6	Moberley (side channel)	15-Jul-12	75	1	LB	40.00	498282	5692304	3.40	W							11	60	0.13
6	**Average**			**1**					**3.50**							**1.45**			**0.97**
6	Moberley (side channel)	15-Jul-12	76	2	RB	9.50	498912	5690360	3.10	W							95	60	1.06
6	Moberley (side channel)	15-Jul-12	77	2	Thalweg	18.50	498902	5690335	3.70	W							125	60	1.39
6	Moberley (side channel)	15-Jul-12	78	2	LB	38.80	498888	5690329	3.10	W							105	60	1.17
6	**Average**			**2**					**3.30**										**1.21**
6	Moberley (side channel)	15-Jul-12	79	3	RB	6.60	498519	5690793	2.10	W	65	60	0.73				135	60	1.51
6	Moberley (side channel)	15-Jul-12	80	3	Thalweg	20.00	498520	5690776	2.80	W	100	60	1.12				140	60	1.56
6	Moberley (side channel)	15-Jul-12	81	3	LM	48.50	498496	5690766	2.70	W	65	60	0.73	65	62	0.70	60	62	0.65
6	Moberley (side channel)	15-Jul-12	82	3	s/c	83.00	498519	5690718	2.10	W				10	54	0.13	60	60	0.67
6	**Average**	15-Jul-12		**3**					**2.43**				**0.86**			**0.42**			**1.10**
6	Moberley (side channel)	15-Jul-12	83	4	Thalweg	49.00	498321	5691125	3.10	W							100	61	1.10
6	Moberley (side channel)	15-Jul-12	84	4	LB	65.30	498315	5691130	3.10	W				100	60	1.12	60	64	0.63
6	Moberley (side channel)	15-Jul-12	85	4	RM	25.20	498355	5691115	2.50	W							115	60	1.28
6	**Average**			**4**					**2.90**							**1.12**			**1.00**
6	Moberley (side channel)	15-Jul-12	86	5	RB	13.10	498428	5691443	3.40	W							80	62	0.87
6	Moberley (side channel)	15-Jul-12	87	5	Thalweg	24.50	498403	5691457	4.00	W				65	60	0.73	150	60	1.67
6	Moberley (side channel)	15-Jul-12	88	5	LM	41.10	498387	5691455	3.40	W							120	60	1.34
6	**Average**			**5**					**3.60**							**0.73**			**1.29**
6	**Mean (SD)**								**3.1 (0.57)**				**0.86 (0.2)**			**0.82 (0.5)**			**1.1 (0.4)**

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Substrate (%) Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other	Cover	Surface Turbidity (NTU's)	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a] Temp (°C)	Cond (us)	DO mg/L	pH	Comments
6	Moberley (side channel)	15-Jul-12	1	RB	25	50	25			Riprap		43	N	N	Y	14.6	179	8.4	8.3	Side channel outlet
6	Moberley (side channel)	15-Jul-12	1	Thalweg		15	60	25				43	N	N	N					
6	Moberley (side channel)	15-Jul-12	1	LB			10	90				43	N	N	N					
6	**Average**		**1**		**8.3**	**21.7**	**31.7**	**38.3**	**0.0**	**0.0**	**0.0**	**43.0**				**14.6**	**179**	**8.4**	**8.3**	
6	Moberley (side channel)	15-Jul-12	2	RB		25	50	25				79	N	N	Y	13.8	178	9.0	8.3	Side channel 40m wide
6	Moberley (side channel)	15-Jul-12	2	Thalweg								80	N	N	N					
6	Moberley (side channel)	15-Jul-12	2	LB								80	N	N	N					
6	**Average**		**2**		**0.0**	**8.3**	**16.7**	**8.3**	**0.0**	**0.0**	**0.0**	**79.6**				**13.8**	**178**	**9.0**	**8.3**	
6	Moberley (side channel)	15-Jul-12	3	RB		20	60	30			N	88	N	N	N	13.7	178	9.0	8.3	
6	Moberley (side channel)	15-Jul-12	3	Thalweg		40	40	20			N	88	N	N	N					
6	Moberley (side channel)	15-Jul-12	3	LM			40	50	10		N	30	N	N	N					
6	Moberley (side channel)	15-Jul-12	3	s/c					100	Veg	Veg	17	N	N	N	15.7	185	7.4	8.2	veg in s/c outflow
6	Moberley (side channel)	15-Jul-12	**3**		**0.0**	**15.0**	**35.0**	**25.0**	**27.5**	**0.0**	**0.0**	**55.7**				**14.7**	**182**	**8.2**	**8.3**	
6	Moberley (side channel)	15-Jul-12	4	Thalweg		10	70	20				59	N	N	N	14.6	180	8.2	8.2	confluence s/c
6	Moberley (side channel)	15-Jul-12	4	LB		10	60	30				40	N	N	N					
6	Moberley (side channel)	15-Jul-12	4	RM			70	30				95	N	N	N					
6	**Average**		**4**		**0.0**	**6.7**	**66.7**	**26.7**	**0.0**	**0.0**	**0.0**	**64.7**				**14.6**	**180**	**8.2**	**8.2**	
6	Moberley (side channel)	15-Jul-12	5	RB								85	N	N	N	13.9	179	8.8	8.3	s/c
6	Moberley (side channel)	15-Jul-12	5	Thalweg		10	60	30				76	N	N	N					
6	Moberley (side channel)	15-Jul-12	5	LM		30	50	20				66	Y	Y	N					
6	**Average**		**5**		**0.0**	**13.3**	**36.7**	**16.7**	**0.0**	**0.0**	**0.0**	**75.5**				**13.9**	**179**	**8.8**	**8.3**	
6	**Summary**				**1.7**	**13.0**	**37.3**	**23.0**	**5.5**	**0.0**	**0.0**	**63.7**				**14.3**	**180**	**8.5**	**8.2**	

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment

Site	Discription	Date	Record #	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Distance from wetted width (m)	UTM Easting	(11N) Northing	Total Depth (m)	Velocity Method (Wading or 50 lb CW)	Velocity Bottom Rev	Velocity Bottom Time(s)	Velocity bottom m/s	Velocity 0.8 Rev	Velocity 0.8 Time(s)	Velocity 0.8 m/s	Velocity 0.2 Rev	Velocity 0.2 Time(s)	Velocity 0.2 m/s
8	Blaeberry	19-Jul-12	100	1	RB	22.00	492942	5699203	2.20	W							50	62	0.54
8	Blaeberry	19-Jul-12	101	1	RM	39.70	492916	5699195	2.00	W							95	62	1.03
8	Blaeberry	19-Jul-12	102	1	Thalweg	67.00	492891	5699197	2.20	W							190	60	2.12
8	Blaeberry	19-Jul-12	103	1	LB	87.50	492873	5699197	3.40	W							125	60	1.39
8	**Average**			**1**					**2.45**										**1.27**
8	Blaeberry	19-Jul-12	104	2	RB	9.50	492993	5699969	3.40	W							65	60	0.73
8	Blaeberry	19-Jul-12	105	2	Thalweg	61.00	492953	5699938	3.70	W							170	60	1.90
8	Blaeberry	19-Jul-12	106	2	LM	89.00	492927	5699928	3.70	W							180	60	2.01
8	Blaeberry	19-Jul-12	107	2	LB	215.00	492826	5699843	2.50	W							150	60	1.67
8	**Average**	15-Jul-12		**2**					**3.33**										**1.58**
8	Blaeberry	19-Jul-12	108	3	RB	17.60	493460	5699146	2.80	W							130	60	1.45
8	Blaeberry	19-Jul-12	109	3	Thalweg	40.60	493481	5699127	1.90	W							110	60	1.23
8	Blaeberry	19-Jul-12	110	3	LB	68.00	493481	5699092	1.50	W							90	60	1.01
8	**Average**			**3**					**2.07**										**1.23**
8	Blaeberry	19-Jul-12	111	4	LB	112.00	493301	5698852	2.80	W							65	60	0.73
8	Blaeberry	19-Jul-12	112	4	Thalweg	62.60	493338	5698889	2.80	W							90	60	1.01
8	Blaeberry	19-Jul-12	113	4	RM	35.00	493336	5698912	2.80	W							135	60	1.51
8	**Average**			**4**					**2.80**										**1.08**
8	Blaeberry	19-Jul-12	114	5	LM	25.00	492733	5698133	4.30	W							70	60	0.78
8	Blaeberry	19-Jul-12	115	5	Thalweg	17.10	492733	5698129	5.00	W							140	60	1.56
8	Blaeberry	19-Jul-12	116	5	RB	7.50	492738	5698133	4.80	W							180	60	2.01
8	**Average**			**5**					**4.70**										**1.45**
8	**Mean (SD)**								**3.04 (1.01)**										**1.33 (0.5)**

Table A1 con't. Habitat Transect Data for seven locations (sites) in the Upper Columbia River: (Upper and Lower) Redgrave, Blaeberry, Moberly (side and main channel), Kicking Horse, and Golden. Transects targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Site	Discription	Date	Transect #	Channel Location (look d/s) (LB/RB, LM/RM, Thalweg)	Substrate (%) Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other	Cover	Surface Turbidity (NTU's)	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a] Temp (°C)	Cond (us)	DO mg/L	pH	Comments
8	Blaeberry	19-Jul-12	1	RB			20	40	40			24	N	N	N					
8	Blaeberry	19-Jul-12	1	RM			40	60				27	N	N	N	16.3	170	8.5	8.6	log jams
8	Blaeberry	19-Jul-12	1	Thalweg		30	40	30				24	N	N	N					
8	Blaeberry	19-Jul-12	1	LB		20	40	60				24	N	N	N					
8	**Average**		**1**		**0.00**	**12.50**	**35.00**	**47.50**	**10.00**	**0.00**	**0.00**	**24.75**				**16.3**	**170**	**8.50**	**8.57**	
8	Blaeberry	19-Jul-12	2	RB		10	50	40				155	Y	N	Y	12.8	178	10.1	8.6	main channel below Blaeberry
8	Blaeberry	19-Jul-12	2	Thalweg		70	30					37	N	Y	N					
8	Blaeberry	19-Jul-12	2	LM		60	30	10				27	N	N	Y	16.4	170	8.6	8.4	Incubation Site
8	Blaeberry	19-Jul-12	2	LB			80	20				23	N	N	N					
8	**Average**	**15-Jul-12**	**2**		**0.00**	**35.00**	**47.50**	**17.50**	**0.00**	**0.00**	**0.00**	**60.60**				**14.6**	**174**	**9.37**	**8.51**	
8	Blaeberry	19-Jul-12	3	RB		10	80	10				170	N	N	N	12.6	179	10.4	8.5	Blaeberry s/c
8	Blaeberry	19-Jul-12	3	Thalweg			30	70				69	N	N	N					
8	Blaeberry	19-Jul-12	3	LB				100				53	N	N	N					
8	**Average**		**3**		**0.00**	**3.33**	**36.67**	**60.00**	**0.00**	**0.00**	**0.00**	**97.33**				**12.6**	**179**	**10.36**	**8.51**	
8	Blaeberry	19-Jul-12	4	LB			30	70				24	N	N	N	16.9	171	8.7	8.5	Blaeberry middle s/c with veg
8	Blaeberry	19-Jul-12	4	Thalweg			40	60				28	N	N	N					
8	Blaeberry	19-Jul-12	4	RM			30	70				28	N	N	N					
8	**Average**		**4**		**0.00**	**0.00**	**33.33**	**66.67**	**0.00**	**0.00**	**0.00**	**26.67**				**16.9**	**171**	**8.72**	**8.47**	
8	Blaeberry	19-Jul-12	5	LM				100				27	N	N	N	16.8	169	8.7	8.4	west s/c
8	Blaeberry	19-Jul-12	5	Thalweg						100		27	N	N	N					
8	Blaeberry	19-Jul-12	5	RB						100		24	N	N	N					
8	**Average**		**5**		**0.00**	**0.00**	**0.00**	**33.33**	**0.00**	**66.67**	**0.00**	**26.00**				**16.8**	**169**	**8.68**	**8.41**	
8	**Summary**					**3.2**	**37.0**	**45.5**	**2.0**	**13.3**	**0.0**	**46.5 (45.1)**				**12.5**	**137.8**	**7.3**	**6.8**	

Table A2 Habitat Transect Data for Egg Plate Locations in the Upper Columbia River (Redgrave, Blaeberry, Moberly, Kicking Horse, and Golden). Locations targeted potential White Sturgeon spawning and embryo hiding habitats for the survival assessment.

Site	Discription	Date	Record #	Transect #	Channel Location	UTM	(11N)	Total Depth (m)	Velocity											
					(look d/s) (LB/RB, LM/RM, Thalweg)	Easting	Northing		Method (Wading or 50 lb CW)	Bottom			0.8			0.2				
										Rev	Time(s)	bottom m/s	Rev	Time(s)	0.8 m/s	Rev	Time(s)	0.2 m/s		
2	Golden	24-Jul-12	205	T4	LM	501001	5682994	5.00	W				205	60	2.29					
3	Upper Redgrave	24-Jul-12	200	T2	RB	480422	5707107	5.80	50				125	60	1.39					
4	Lower Redgrave	24-Jul-12	201	T1	RB	479004	5706119	8.00	50				110	60	1.23					
5	Below Kicking Horse	24-Jul-12	204	T5	LB	498433	5688184	3.90	W				120	61	1.32					
6	Moberly side channel	24-Jul-12	203	T1	RM	498157	5692535	3.00	W				90	60	1.01					
8	Blaeberry	24-Jul-12	202	T2	LM	492863	5700042	2.70	W				195	60	2.17					

Site	Discription	Date	Transect #	Channel Location	Substrate (%)						Cover	Surface Turbidity	Sediment Sample #	Water Sample #	Benthos Sample #	YSI Profile [a]			
				(look d/s) (LB/RB, LM/RM, Thalweg)	Boulder	Cobble	Gravel	Sand	Silt/ Clay	Bedrock / Other		(NTU's)				Temp (°C)	Cond (us)	DO mg/L	pH
2	Golden	24-Jul-12	T4	LM	0	50	30	20	0	0		6	N	N	N	16.9	151	7.5	8.4
3	Upper Redgrave	24-Jul-12	T2	RB	30	70	0	0	0	0		40				13.8	173	9.7	8.8
4	Lower Redgrave	24-Jul-12	T1	RB	60	40	0	0	0	0		40				13.8	173	9.3	
5	Below Kicking Horse	24-Jul-12	T5	LB	0	60	20	20	0	0		15				15.5	160	8.2	8.6
6	Moberly side channel	24-Jul-12	T1	RM	0	30	50	20	0	0		36				14.2	172	8.9	8.7
8	Blaeberry	24-Jul-12	T2	LM	0	50	50	0	0	0		20				14.6	170	8.5	8.8

Appendix B

Habitat Assessment Sites Showing Transect Locations

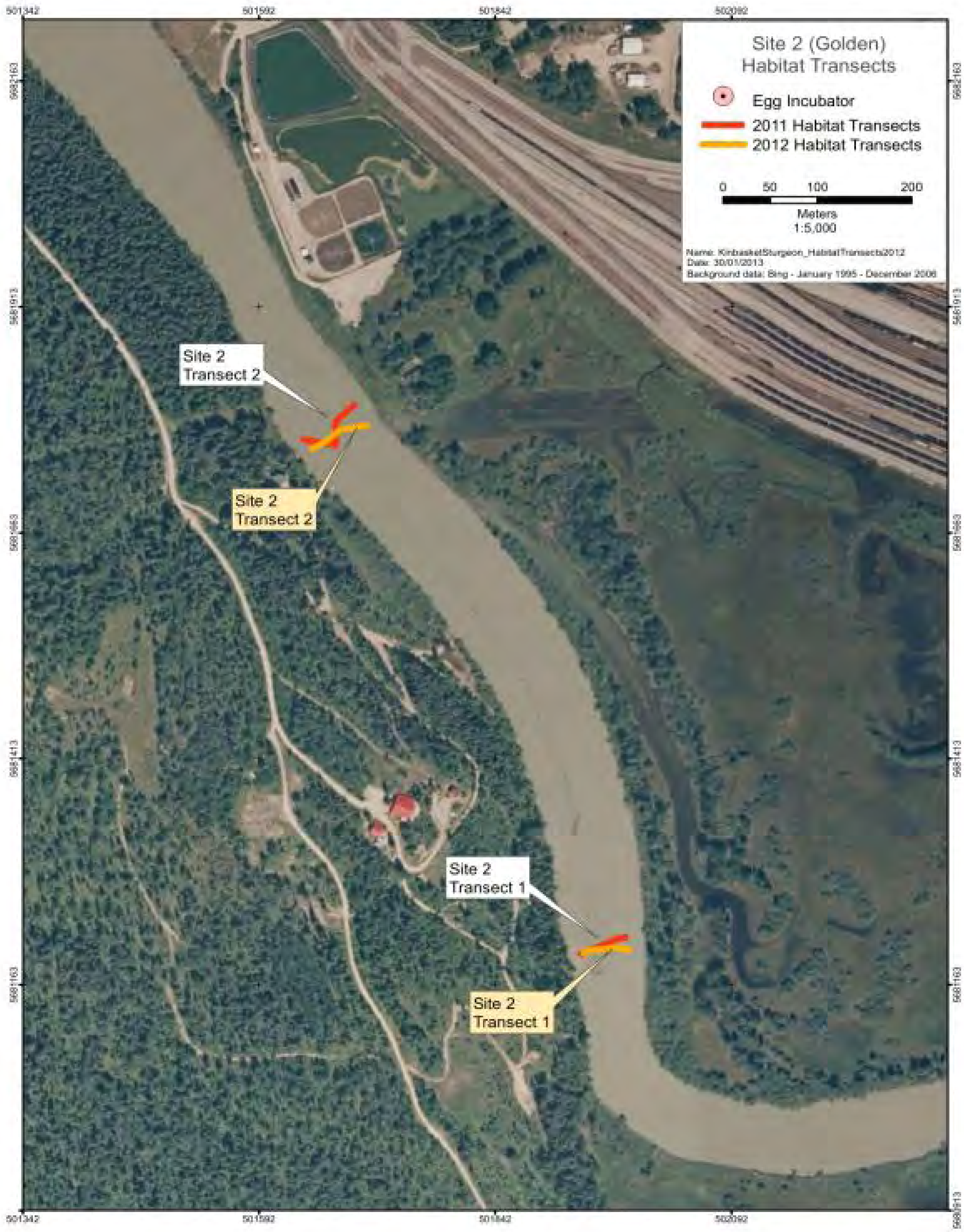

Figure B1 Habitat assessment Site 2 at Golden B.C. The overview shows transect locations in order from upstream (transect 1) to downstream (transect 5). (Note the upper Columbia River flows north to Kinbasket Reservoir). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

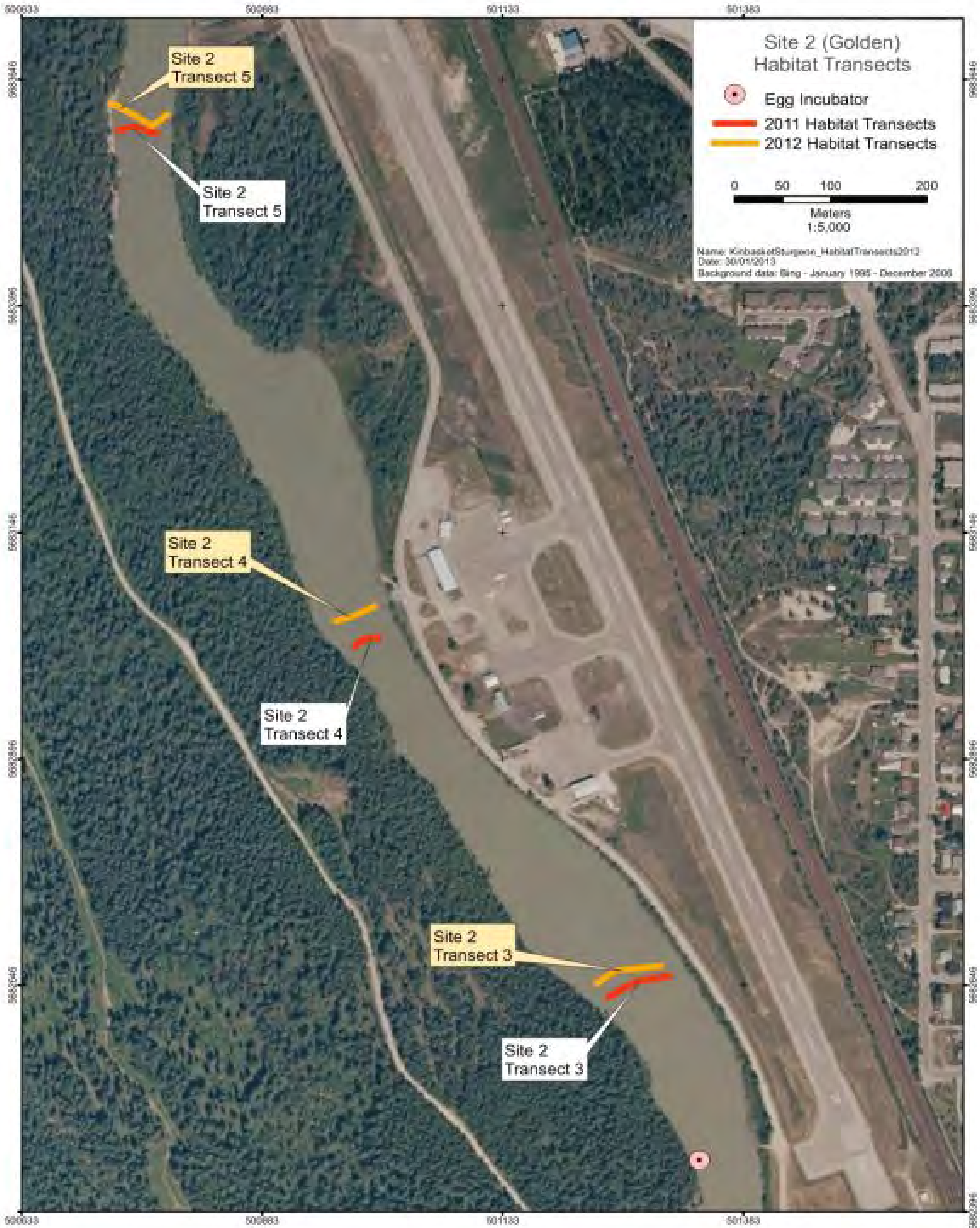

Figure B1 con't Habitat assessment Site 2 at Golden B.C. The overview shows transect locations in order from upstream (transect 1) to downstream (transect 5). (Note the upper Columbia River flows north to Kinbasket Reservoir). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

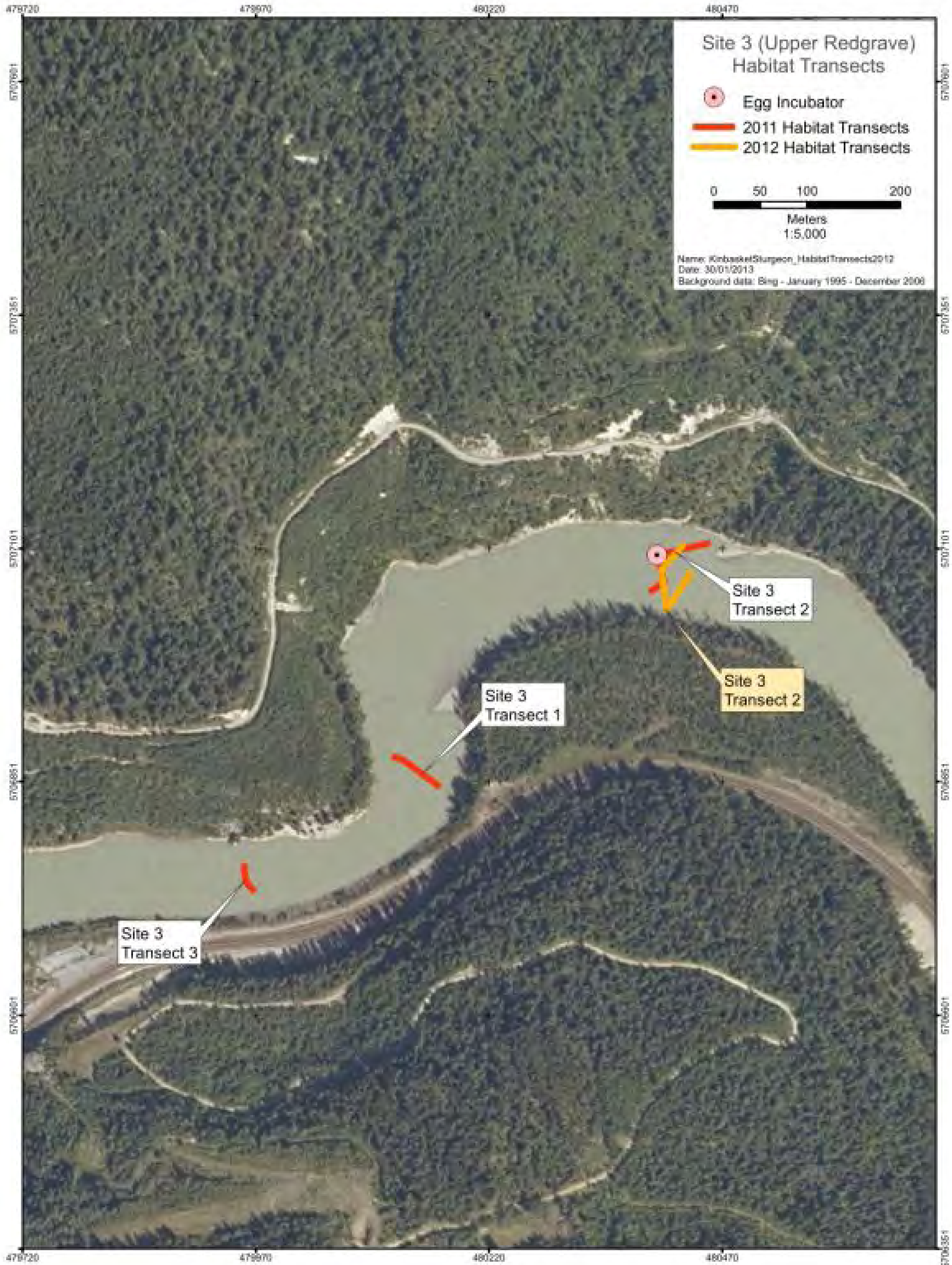

Figure B2 Habitat assessment Site 3 at Redgrave rapids (immediately downstream of the canyon). The overview shows transect locations in order from upstream (transect 2) to downstream (transect 3). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

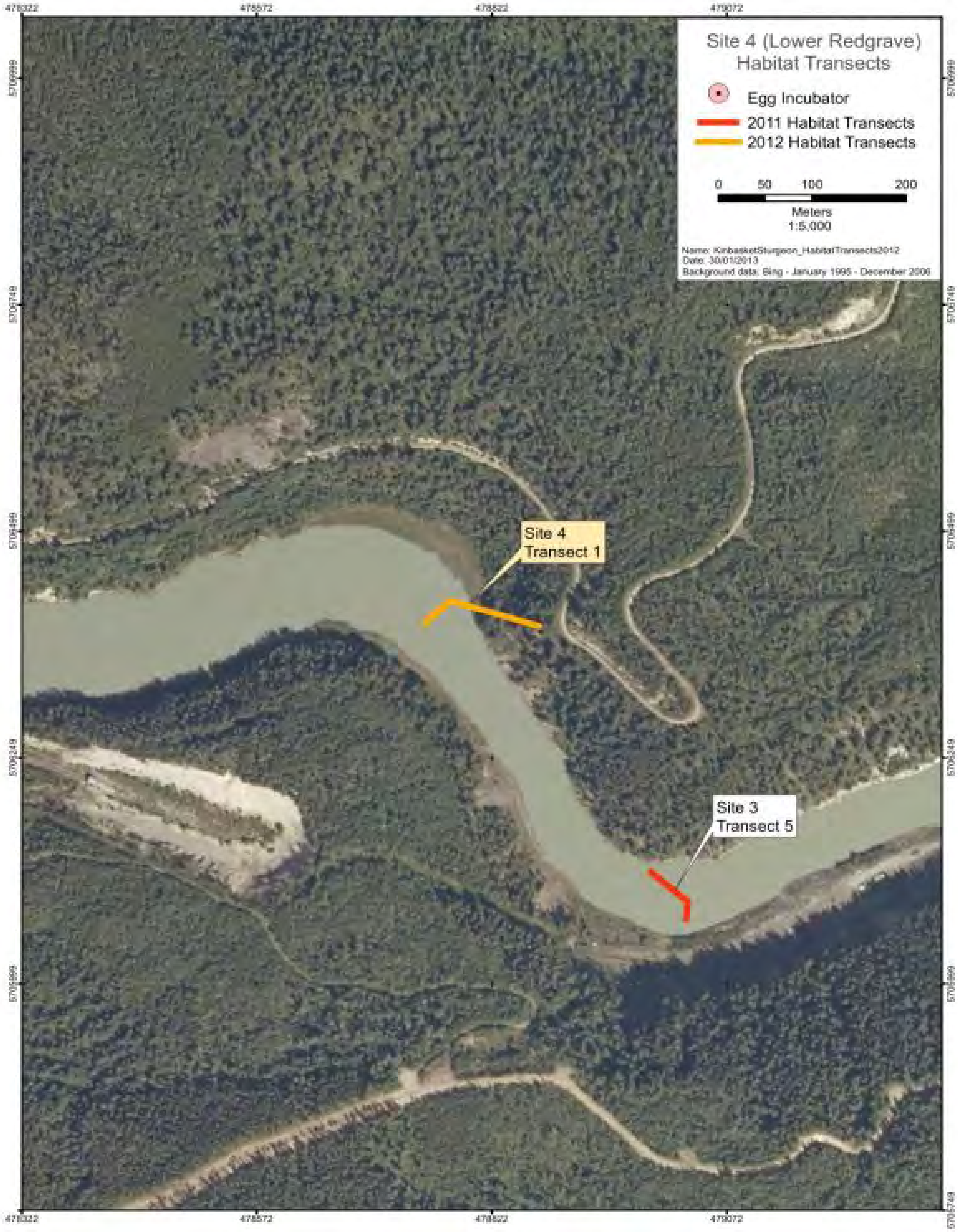

Figure B3 Habitat assessment Site 4 downstream of Redgrave rapids. The overview shows transect locations in order from upstream (transect 5 upper Redgrave to transect 1 lower Redgrave). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

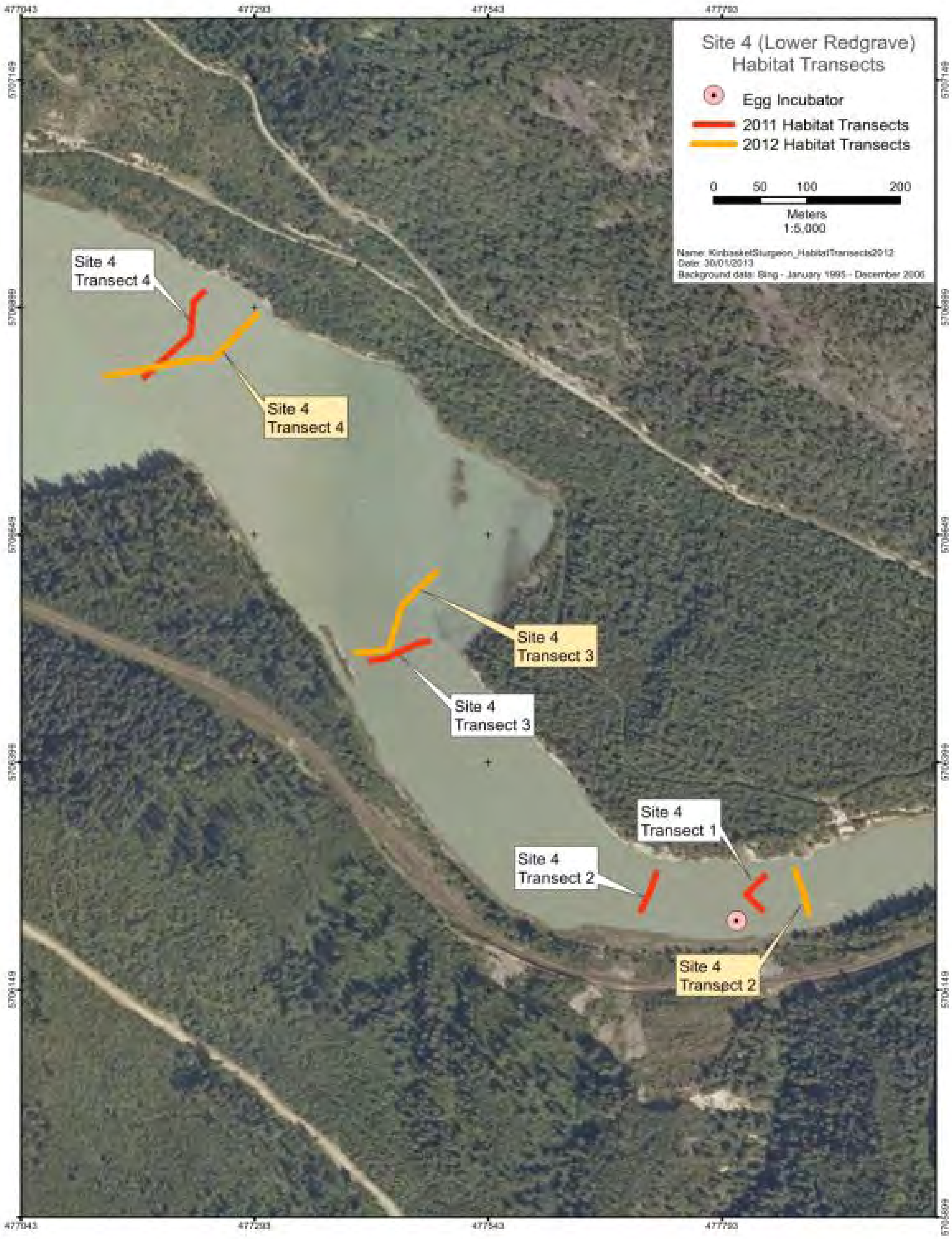

Figure B3 cont. Habitat assessment Site 4 downstream of Redgrave rapids. The overview shows transect locations in order from upstream (transect 1) to downstream (transect 4). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Figure B4 Columbia River Habitat Assessment Site 5 immediately downstream of Kicking Horse River. The overview shows transect locations in order from upstream (transect 3) to downstream (transect 1). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Figure B4 cont. Columbia River Habitat Assessment Site 5 immediately downstream of Kicking Horse River. The overview shows transect locations in order from upstream (transect 4) to downstream (transect 5). Within each transect measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

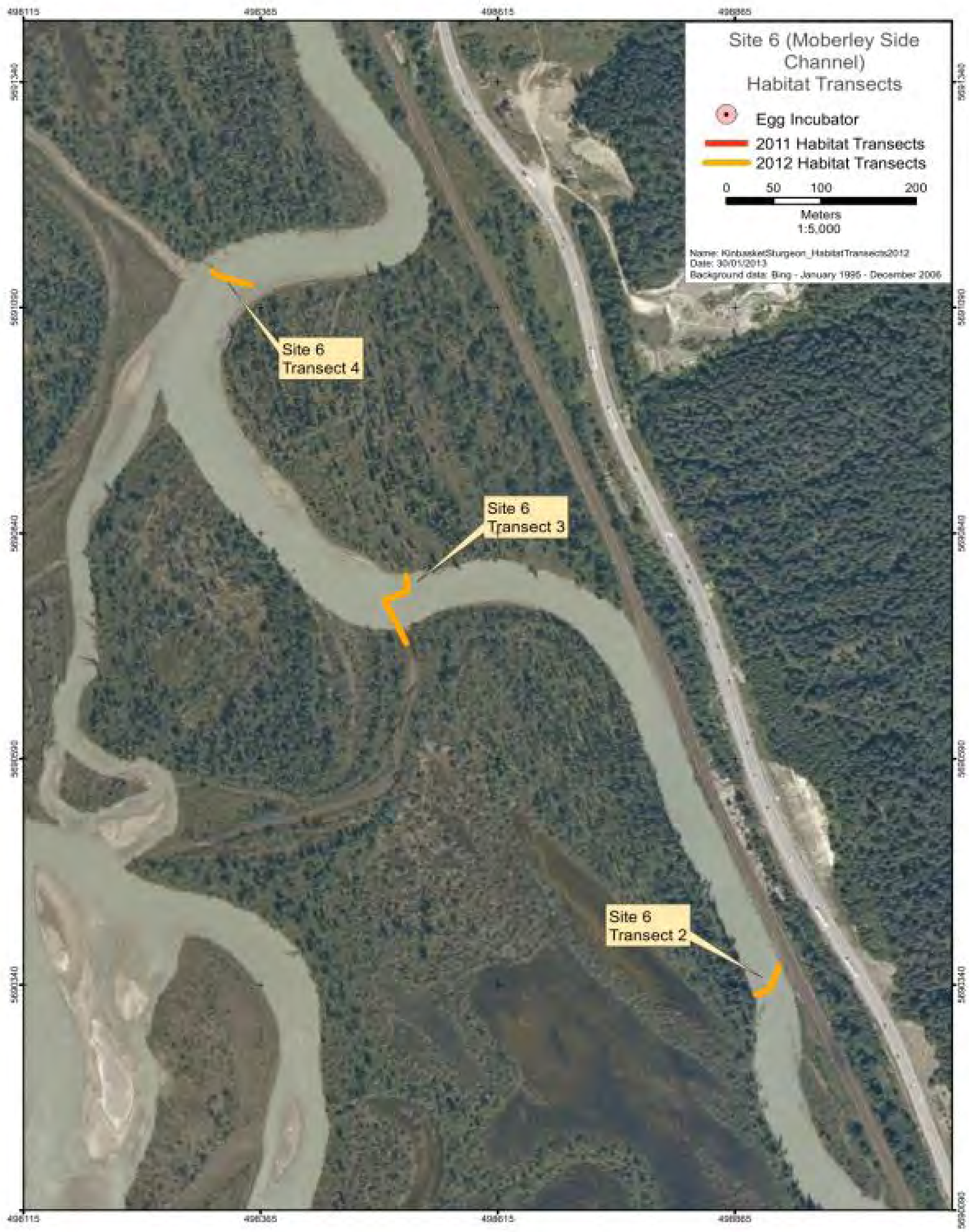

Figure B5 Columbia River Habitat Assessment Site 6 in a side channel at Moberly BC. The overview shows transect locations in order from upstream (transect 2) to downstream (transect 4). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

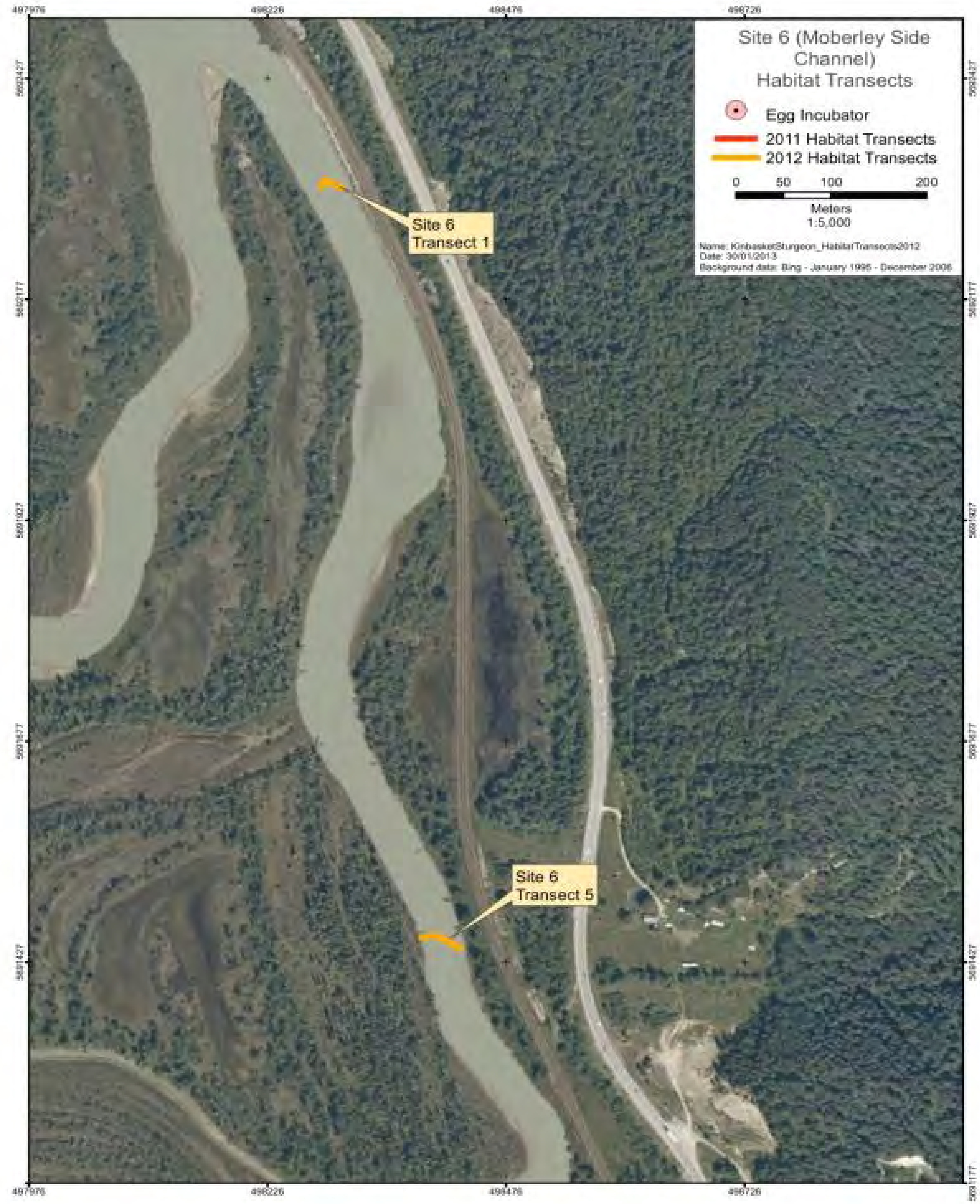

Figure B5 cont. Columbia River Habitat Assessment Site 6 in a side channel at Moberly BC. Transect 5 is downstream transect 1 (Figure B5). Within each transect measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

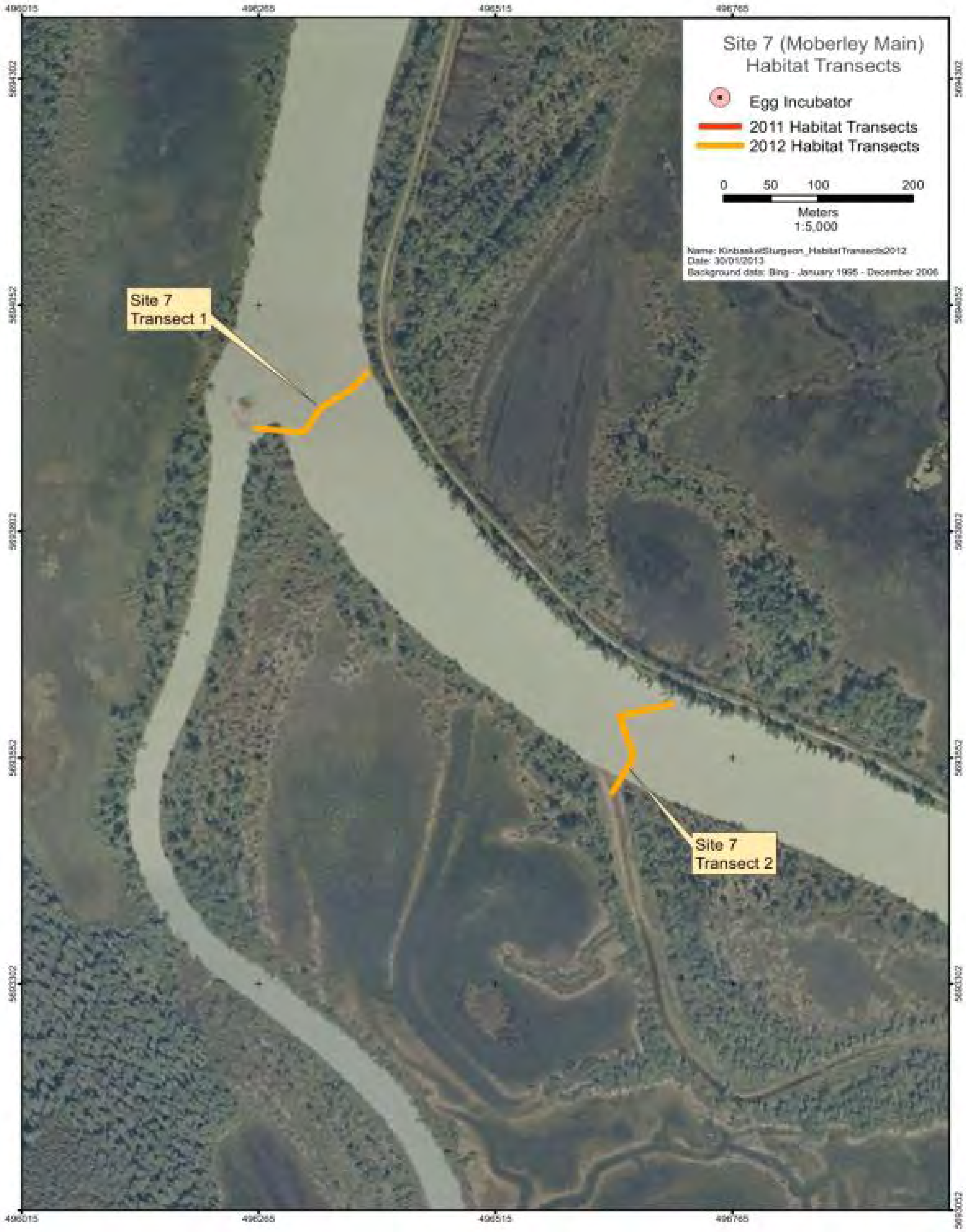

Figure B6 Columbia River Habitat Assessment Site 7 in the main channel at Moberly BC. The overview shows transect locations in order from upstream (transect 2) to downstream (transect 1). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

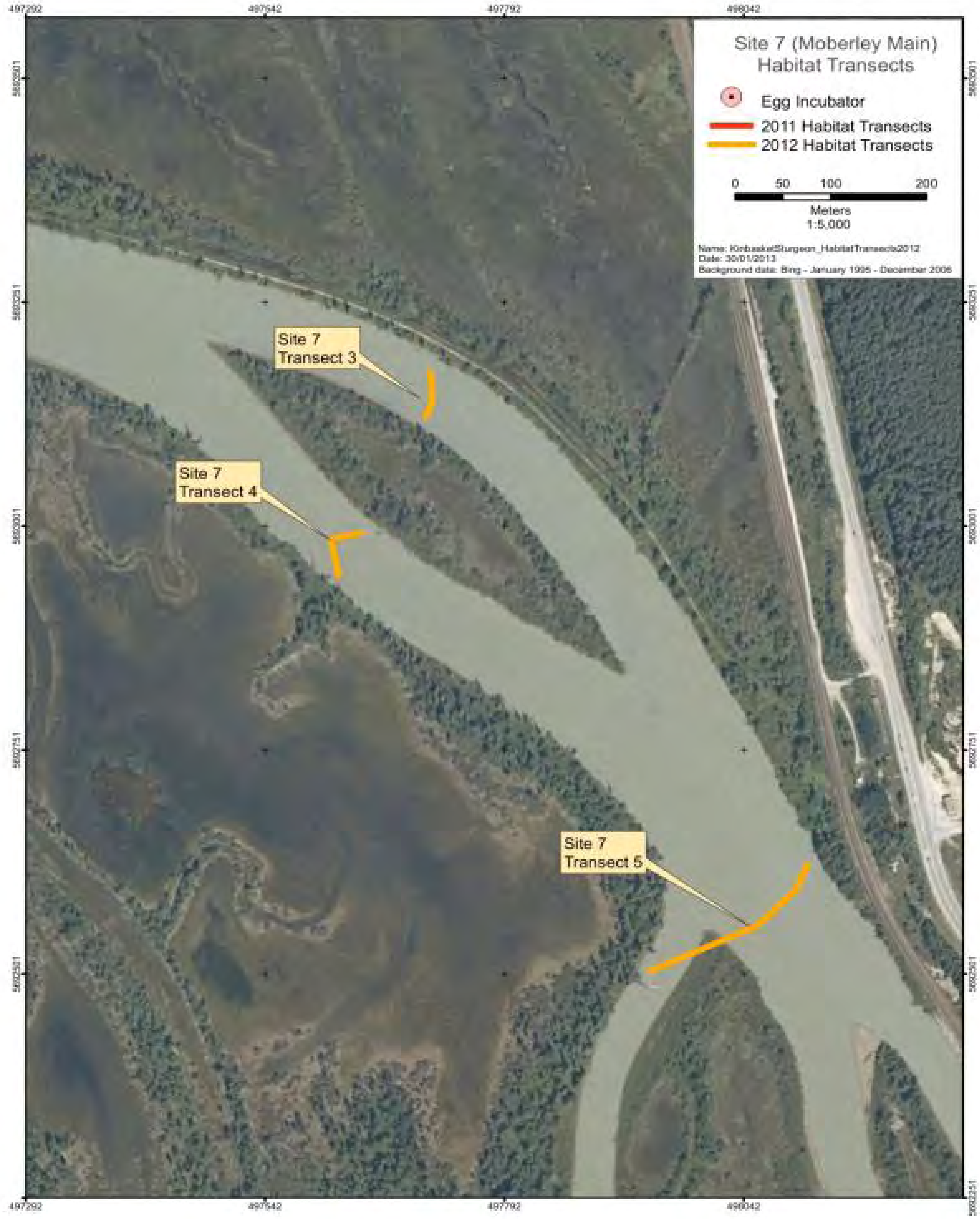

Figure B6 cont. Columbia River Habitat Assessment Site 7 in the main channel at Moberly BC. The overview shows transect locations in order from upstream (transect 5) to downstream (transect 3). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

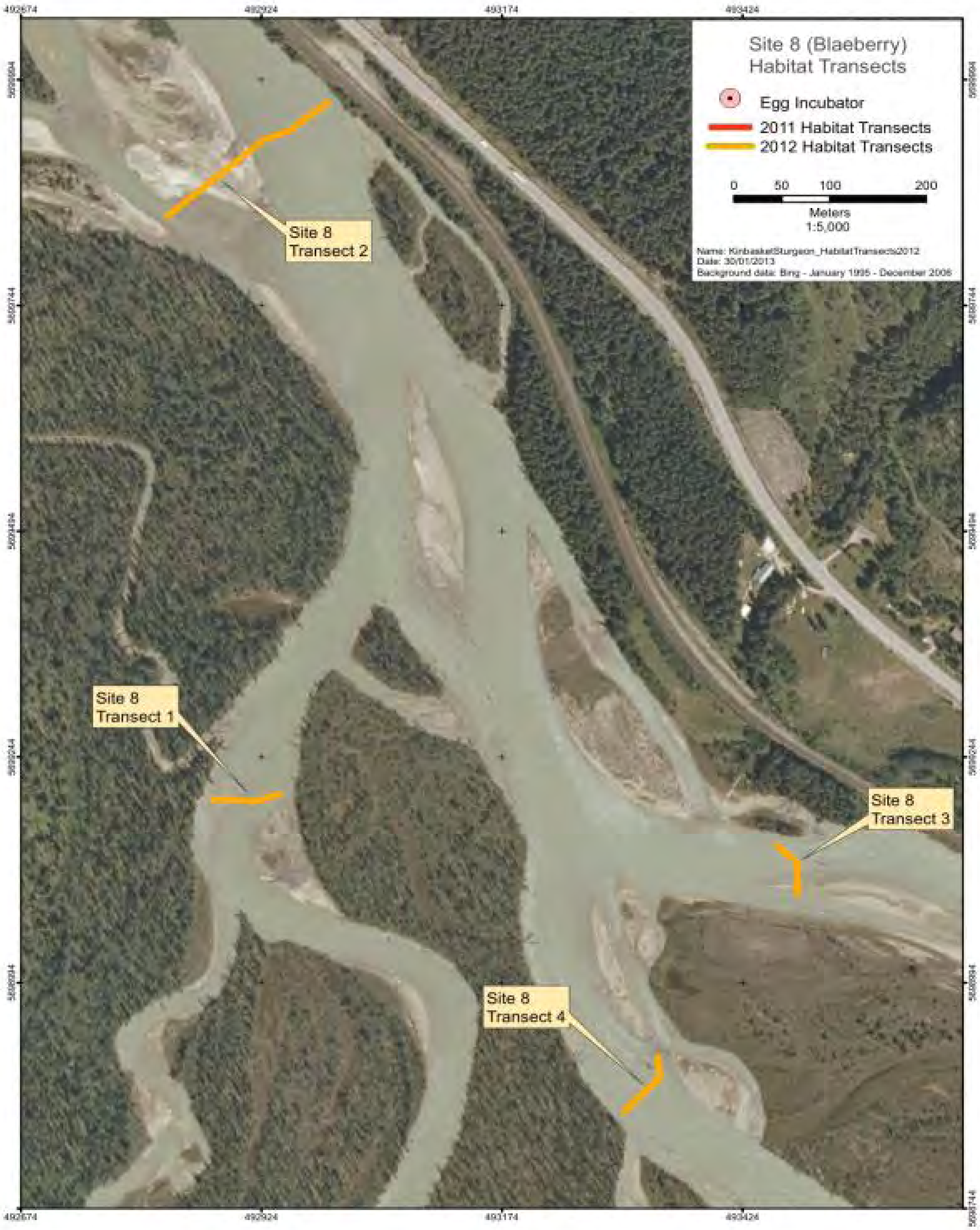

Figure B7 Columbia River Habitat Assessment Site 8 at Blaeberry BC. The overview shows transect locations in order from upstream (transect 4) to downstream (transect 2). Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Figure B7 con't Columbia River Habitat Assessment Site 8 at Blaeberry BC. Transect 5 is the most downstream measurement at this site. Within each transect, measurements of depth, velocity, substrate and turbidity were taken at five locations: right bank (RB), right midbank (RM), thalweg, left midbank (LM) and left bank (LB).

Appendix C

Contaminant Data

Table C1 Contaminant data for soil/sediment samples from five locations (sites) in the Upper Columbia River. Locations targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Sample Type	Parameter	Golden Airport (Site 2)		Downstream Kicking Horse (Site 5)		Moberly Side Channel (Site6)		Below Blaeberry (Site 8)		Lower Redgrave (Site 4)	
		Jul12 rep1	*Jul12 rep2*	*Jul17 rep1*	*Jul17 rep2*	*Jul17 rep1*	*Jul17 rep2*	*Jul21 rep1*	*Jul21 rep2*	*Jul12 rep1*	*Jul12 rep2*
Soil	pH	8.55	8.04	8.67	8.6	8.68	8.72	8.89	8.83	8.42	8.42
	PCB's	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
	Aluminum (mg/kg)	8610	8400	8530	7590	7390	7360	7160	7630	9220	9210
	Antimony	0.2	0.44	0.26	0.2	0.2	0.19	0.12	0.14	0.25	0.3
	Arsenic	9.16	9.11	7.42	5.68	5.31	5.39	2.8	2.29	6.34	6.78
	Barium	61.9	187	156	155	182	204	42.3	42.9	124	133
	Beryllium	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
	Bismuth	<0.1	<0.1	0.1	<0.10	<0.10	<0.10	<0.1	0.11	0.16	0.18
	Cadmium	0.096	0.112	0.175	0.135	0.203	0.217	0.122	0.119	0.272	0.287
	Calcium	9020	11200	85700	87400	109000	113000	136000	135000	107000	106000
	Chromium	16.5	16.1	14	12.7	12.6	12.5	11.8	12.9	14.7	14.6
	Cobalt	7.89	7.94	8.58	7.72	7.3	7.18	6.85	7.09	9.89	10.2
	Copper	7.21	7.31	11.8	10.7	10.6	10.2	10.1	8.71	18.2	21.3
	Iron	21600	21500	23000	21300	21200	21200	18900	20000	24400	24200
	Lead	11.3	11	18	17	21.8	22	9.52	9.31	24.2	26.7
	Lithium	23.8	22.7	20.8	18.6	18	18.2	18.6	19.8	23.5	23.4
	Magnesium	7570	8160	26900	28200	36300	37600	38900	37300	31300	30200
	Maganese	300	306	446	424	448	452	435	434	532	545
	Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Molybdenum	0.3	0.27	0.54	0.65	0.59	0.58	0.3	0.27	0.51	0.55
	Nickel	19.5	19	18.4	17.3	16	15.3	15.2	15.8	19.4	19.5
	Phosphorus	279	372	465	508	534	561	465	466	514	511
	Potassium	235	246	430	364	406	440	295	344	435	445
	Seleneium	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Silver	<0.05	0.52	0.06	<0.05	0.06	0.062	<0.05	<0.05	0.089	0.077
	Sodium	<100	<100	138	136	122	122	<100	<100	<100	<100
	Strontium	18.1	24.2	150	155	171	173	214	216	183	182
	Thallium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Tin	0.13	0.14	0.15	<0.10	0.11	0.1	0.63	0.11	0.18	0.27
	Titanium	45.5	52.7	90.3	77	99	105	28.6	27.8	56.8	63.9
	Uranium	0.562	0.75	0.542	0.473	0.499	0.665	0.445	0.349	0.75	0.755
	Vanadium	7.6	8.6	9	8.4	9.8	9.9	6.8	6.1	9.1	8.9
	Zinc	44	44.2	63.4	60.4	75.6	74.8	39.1	41.3	65.2	65.2
	Zirconium	1.35	1.4	2.46	2.14	2.31	1.96	2.62	2.58	1.49	2.42

Table C2. Contaminant data for water samples from five locations in the Upper Columbia River. Locations targeted potential White Sturgeon spawning and embryo hiding habitats for the assessment.

Sample Type	Parameter	Golden Airport (Site 2)		Downstream Kicking Horse (Site 5)		Moberly Side Channel (Site6)		Below Blaeberry (Site 8)		Lower Redgrave (Site 4)	
		Jul12 rep1	*Jul12 rep2*	*Jul17 rep1*	*Jul17 rep2*	*Jul17 rep1*	*Jul17 rep2*	*Jul21 rep1*	*Jul21 rep2*	*Jul12 rep1*	*Jul12 rep2*
Water	Total Hardness	81.6	81	88.7	109	99.2	101	102	110	160	148
	TSS (mg/L)	11.8	13.8	21.9	23	38	35.8	66	72	91.2	83.9
	turbidity	5.1	5.12	12	13.1	30.9	34.2	35.9	37.7	72.5	66.1
	PCB's	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Aluminum (mg/kg)	214	172	398	712	395	370	869	1190	1470	1250
	Antimony	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Arsenic	0.99	0.82	0.99	1.26	0.72	0.68	0.9	1.04	1.1	0.99
	Barium	47.8	45.8	44.5	65.5	37.8	38.2	43.5	46.4	44.2	43.7
	Beryllium	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	Bismuth	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Boron	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Cadmium	0.01	<0.1	<0.01	0.016	0.015	0.018	0.019	0.02	0.036	0.027
	Chromium	<1.0	<1.0	<1.0	1.4	<1.0	<1.0	1.3	1.7	2.3	2
	Cobalt	<0.50	<0.50	<0.5	0.75	<0.5	<0.5	0.69	0.83	1.38	1.1
	Copper	1.01	0.86	1.32	2.01	1.03	1.24	1.43	2.9	2.65	2.44
	Iron	652	438	846	1630	692	687	1360	1690	2910	2470
	Lead	0.67	0.56	1.03	2.05	1.09	1.15	1.54	1.62	2.66	2.23
	Lithium	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Maganese	26.5	23.1	30.4	55.7	24.8	25.6	40.5	47.5	83.5	71.6
	Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Molybdenum	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Nickel	<1.0	<1.0	1.5	1.7	<1.0	<1.0	1.4	1.8	2.5	2.1
	Seleneium	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Silicon	1630	1630	1900	2310	1950	2000	2660	2960	3030	2880
	Silver	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	Strontium	82.9	84.1	95.6	108	139	140	126	136	193	186
	Thallium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Tin	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Titanium	<5.0	5	5.3	10.1	6.9	8	11.4	23	31.1	22.4
	Uranium	0.4	0.43	0.32	0.37	0.34	0.32	0.36	0.46	0.42	0.39
	Vanadium	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Zinc	<5.0	<5.0	<5.0	6.7	<5.0	<5.0	5.3	6.5	9.8	9
	Zirconium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.68	0.78	<0.5
	Calcium	19	19.1	21.9	26.9	25.4	26	26.2	28	42.8	40
	Magnesium	8.31	8.1	8.24	10.1	8.7	8.83	8.89	9.73	12.8	11.7
	Potassium	0.476	0.456	0.529	0.597	0.568	0.574	0.705	0.77	0.729	0.715
	Sodium	0.824	0.81	0.75	0.777	0.859	0.853	0.767	0.792	1.21	0.943
	Sulphur	4.9	4.8	5	4	3.7	3.9	<3.0	3.6	5	4

Appendix D

Benthos Data

Table D1 Food types and sizes available at potential larval and YOY rearing habitats in the upper Columbia River.

				2011			2012		
Site	**Order**	**Family**	**Genus**	**4 mm**	**1 mm**	**125 um**	**4 mm**	**1 mm**	**125 um**
Golden	**Substrate**			**60% gravel 40% sand**			**80% sand 20% organic fines**		
	Cladocera	Daphnidae				13			5
	Copepoda (suborder)	Cyclopoida (order)				1			
	Copepoda (suborder)	Calanoida (order)				1			
	Diptera	Ceratopogonidae			1				
	Diptera	Chironomidae	Podonominae		4				
	Diptera	Chironomidae			2	1		1	2
	Diptera	Simulidae	Prosimulium		1				
	Diptera	Simulidae	Simulium			1			
	Diptera	Chaoboridae				1			
	Diptera	Tipulidae							1
	Gastropoda	Lymnaeidae						1	1
	Oligochaeta	Naididae		1	1	3			
	Tripchoptera	Limnephilidae	Onocosmoecus	1					
	Ephemeroptera	Ephemerellidae	Ephemerella	1					
	Ephemeroptera	Ephemerellidae	Serratella			1			
	Ephemeroptera	Heptageniidae	Rhithrogena		8	1		1	
	Ephemeroptera	Heptageniidae			1				
	Plecoptera	Perlodidae	Pictetiella	1	1	3			
	Plecoptera	Perlodidae	Rickera		1	2			
	Plecoptera	Perlodidae				1			
Kicking Horse	**Substrate**						**20% cobble/60% gravel/ 20% sand**		
	Diptera	Athericeridae	Atherix				1	1	
	Diptera	Ceratopogonidae							2
	Diptera	Simulidae					14	8	236
	Diptera							3	1
	Cladocera	Daphnidae							1
	Ephemeroptera	Ephemerellidae	Ephemerella				2		
	Ephemeroptera	Heptageniidae	Rhithrogena				1	1	
	Plecoptera	Capniidae						1	1
	Plecoptera	Perlodidae	Isoperla				3	1	
	Plecoptera	Siphlonuridae	Parameletus					1	
	Trichoptera	Hydropsychidae	Ceratopsyche				1	1	
Moberly Main	**Substrate**						**80% sand/ 20% silt**		
	Annelida (Class Hirudinea)						1[a]		
	Diptera	Chironomidae					3[a]	1	5[a]
	Diptera	Simulidae					1[a]		
	Gastropoda	Planorbidae						2	
	Gastropoda	Lymnaeidae						1	
	Oligochaeta	Naididae							5[a]
	Ostrocoda								1[a]
	Tricoptera	Brachycentridae						1	
	Tricoptera							1	
	tadpole								
Moberly Side	**Substrate**						**25% boulder/50% cobble/ 25% gravel**		
	Cladocera	Daphnidae							7
	Diptera	Chironomidae							2
	Diptera	Simulidae							1
	Ephemeroptera	Ephemerellidae	Ephemerella					1	2
	Ephemeroptera	Ephemerellidae							1
	Gastropoda	Lymnaeidae						1	
	Gastropoda	Planorbidae						1	
	Oligochaeta	Naididae							1
	Plecoptera	Perlodidae					1	1	
	Tricoptera	Leptoceridae							1
	Tricoptera								1
Blaeberry	**Substrate**						**60% cobble/ 30% gravel/ 10% sand**		
	Cladocera	Daphnidae							23
	Diptera	Chironomidae							1
	Diptera								2
	Oligochaeta	Naididae							1
Upper Redgrave	**Substrate**			**10% boulder/20% cobble/ 10% gravel/ 10% sand/50% clay**			**10% cobble/ 40% gravel/ 30% sand/20% silt**		
	Diptera	Ceratopogonidae		1			1[a]		
	Diptera	Chironomidae		5					2
	Diptera	Chironomidae							1[b]
	Diptera	Chironomidae	Podonominae						1[b]
	Diptera	Simulidae	Prosimulium		1				1
	Gastropoda	Planorbidae		1				1	
	Oligochaeta	Lumbriculidae		1					
	Oligochaeta	Naididae		1	7		1[a]		2[b]
	Ephemeroptera	Ephemerellidae	Ephemerella		1			1	
	Ephemeroptera	Heptageniidae	Epeorus		1	1			
	Ephemeroptera	Heptageniidae	Stenonema			1			
	Ephemeroptera	Siphlonuridae	Parameletus	1	1	6			
	Ephemeroptera			1		1			
	Lepidoptera							1	
	Plecoptera	Perlodidae	Isoperla		4	2			
	Plecoptera	Perlodidae		1			1[a]		1[b]
	Trichoptera			1	1				

[a] this fraction subsampled 1/8 of whole
[b] this fraction subsampled 1/4 of whole