Wahleach Project Water Use Plan

Channel Stability Assessment

WAHMON#2

*Lower Jones Creek Channel Stability Assessment*

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(NHC) Northwest Hydraulic Consultants
Wahleach Water Use Plan Monitoring Program
Lower Jones Creek Channel Stability Assessment, 2005-06

Final Report
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Submitted to:

BC Hydro and Power Authority
10600 Wilson Street
Mission, BC  V4S 1B4
Attention: Mr. Dave Hunter

Submitted by:

northwest hydraulic consultants ltd
30 Gostick Place
North Vancouver, BC  V7M 3G3
Contact: Craig Nistor, P.Geo.
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EXECUTIVE SUMMARY

The Lower Jones Creek Channel Stability Assessment was established by BC Hydro as part of the Wahleach Water Use Plan Monitoring Program to investigate the extent to which channel stability and substrate quality limit fish productivity in Lower Jones Creek. Channel stability and substrate quality were evaluated by a series of repeat surveys and photographic samples taken between Autumn 2005 and Spring 2006, roughly coinciding with peak spawning, midway through incubation, and end of incubation for pink salmon, the target species in Lower Jones Creek. Topographic surveys and photographic samples were collected at five previously established cross-sections – referred to as Sections 4, 6, 8, 9 and 10 (downstream to upstream).

Overall, the channel changes observed in Lower Jones Creek during the study period were relatively small compared to the anecdotal and visual evidence of past channel activity. Where changes in bed elevation were observed, they were typically in the range of 0.1 to 0.2 m at one or two survey points, which is barely above the level of survey detectability. In the first period – October 2005 through February 2006 – minor scour was observed at three of the five sections, likely resulting from the occurrence of several moderate flow events during the period. In the second period – February through April 2006 – minor fill was observed at four of the five sections, likely resulting from the occurrence of smaller flow events during this period. There were no observed changes in the position of the wetted low-flow channel that could be detected above the minor variations in wetted edge position associated with variations in flow. Therefore, there was no detectable abandonment of spawning habitat due to channel migration.

Estimation of material size during the topographic surveys indicated a distinct fining of the bar and secondary-channel surface material between October 2005 and February 2006 at Section 6. A more extensive fining of bar surface material was observed at Section 8 throughout the study period (October 2005 through April 2006), with the area of fine material extending into the wetted channel. At both sections, negligible fill thicknesses were observed in conjunction with the substrate fining, most likely indicating a thin layer of fine sediment deposition over gravel.
Photographic substrate grain-size distributions indicated the greatest changes occurred at Section 8. This corresponds with our survey observations of an expanding extent of fine sediment cover on the bar extending into the wetted channel. The content of fine gravels, 1 to 9.5 mm in size, increased from 7% to 18%, between December and February. More dramatically, the content of fine sediment less than 1 mm in size increased from 6% in December and February to 42% in May; although this trend may be exaggerated because of improvements in the quality of photo samples and a decrease in the sample size over time. At Sections 9 and 10, the fractions of fine gravels increased from 14% and 15%, respectively, in December to 33% and 34%, respectively, in February. Subsequently, the fine gravel content at Section 9 increased further from 33% to 37% in May, whereas it decreased from 34% to 28% in May at Section 10. Changes in substrate composition were less marked at Sections 4 and 6.

The analysis contained herein consists of independent analyses of topographic and substrate data at each of the five cross-sections. A composite volumetric analysis of bed surface change throughout the study reach would require the collection of additional topographic data between cross-sections. The channel is particularly wide and complex between Sections 6 and 8. Additional topographic data would certainly be needed in that area in particular before any volumetric estimates could be attempted.

Photographic sampling techniques have evolved over the monitoring period and the current apparatus represents a considerable improvement over our initial technique. However, the field of view is significantly smaller than our previous sampling apparatus. Therefore, several non-overlapping photographs should be taken at each photo sample point to provide larger sample sizes during future monitoring work.
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1. Introduction

Wahleach Creek (also unofficially known as Jones Creek) flows northward into the Fraser River about 16 km west of Hope, BC (Figure 1, Figure 2 inset). The creek’s watershed covers an area of 115 km² in the rugged terrain of the Cascade Mountains. After emerging from the mountains, the creek flows across an alluvial fan for approximately 900 m before joining the Fraser River. The fan reach of the creek is commonly referred to as Lower Jones Creek.

BC Hydro and Power Authority (BC Hydro) owns and operates the Wahleach hydroelectric project. The project consists of a dam on Wahleach Lake – located about 8 km upstream from the mouth of Jones Creek – and a diversion tunnel from Wahleach Lake to a generating station near Herrling Island on the Fraser River (Figure 2). Approximately 88 km² of the watershed area, or 77% of the total watershed, drains into Wahleach Lake. Operation of the Wahleach project began in 1952, altering the pattern and size of flows downstream of the dam site. Peak flow has been reduced by as much as 65% and average annual flow has been reduced by over 80% (MMAL 1997). Compensation measures to reduce the fisheries impacts associated with the hydroelectric project began soon after the construction of the dam, with the development of a spawning/rearing channel adjacent to Lower Jones Creek. The artificial channel – designed to provide habitat primarily for pink salmon – was plagued by sedimentation problems and has now been abandoned.

BC Hydro’s Wahleach Water Use Plan (WUP) now sets seasonal instream flow requirements for pink salmon in Lower Jones Creek. However, the effectiveness of these flows at maintaining pink salmon productivity is not known due to the potentially more significant effects of channel...
 instability and sedimentation in the creek channel. The Lower Jones Creek Channel Stability Assessment was initiated in 2005 under the Wahleach WUP Monitoring Program to evaluate the effects of channel instability and sedimentation on pink salmon productivity during the spawning and incubation phases of their life cycle.

1.1 Background

The Lower Jones Creek study reach lies between the Laidlaw Road bridge near the apex of the fan, and the Highway 1 bridge near the mouth of the creek (Figure 2). BC Hydro operates a streamflow gauging station (BCH_LJC) immediately downstream of the Laidlaw Road bridge. A buried oil pipeline crosses the beneath the creek channel approximately 200 m downstream of the Laidlaw Road bridge. A small tributary, Lorenzetta Creek, enters Lower Jones Creek approximately 80 m upstream from the mouth.

The creek channel is incised on the upper part of the fan, from the apex to a point shortly downstream of the pipeline crossing. In this section, the channel is approximately 10 m in bottom width and is confined within banks 3 to 4 m in height. Exposed tree roots in the banks indicate significant channel downcutting through fan deposits in recent decades. The channel bed is comprised mainly of coarse, infrequently mobile material, with pockets of finer material in protected areas between the boulders.

Below the pipeline crossing, the channel widens dramatically (40 to 50 m in width) and is bounded by lower banks (1 to 2 m in height). The channel is characterized by wide bars of gravel and sand which are inundated only during high runoff events. The normally wetted, low-flow channel occupies only a small portion of the active flood channel (typically around 10 m). This part of the fan channel is subject to active sediment deposition and lateral channel activity.

Near the mouth of the creek, Fraser River exerts a seasonal backwater influence on Jones Creek water levels. The Fraser River hydrograph is dominated by snowmelt with maximum levels occurring between May and July. During this period, the lowermost 200 m of Jones Creek are affected by Fraser River backwater. Jones Creek also experiences a modest spring freshet resulting from snowmelt in the watershed below Wahleach Lake. However, the largest
flows typically occur during rainfall and rain-on-snow events in the autumn and winter, typical of small basins in coastal British Columbia.

The Lower Jones Creek spawning / rearing channel and associated structures are shown on Figure 2 (based on Figure 5.3.1, MMAL 1997). A concrete diversion weir, located approximately 90 metres downstream of Laidlaw Road bridge, was designed to feed water into the habitat channel. At the downstream end of the channel, a 1.5-m high, 70-m long structure was built across Lower Jones Creek, to encourage fish into the habitat channel. This structure was replaced in 1992 and 1993, and was partially dismantled in 2005. Remnants of the fish diversion weir are apparent; large angular riprap material exists near the old weir site providing a hydraulic drop in the channel. Portions of the upstream diversion weir can still be seen in the channel although the remaining portions are extensively buried. Remnants of concrete-block bank protection works are visible along parts of the left bank of Jones Creek.

1.2 Objectives and Approach

BC Hydro and watershed stakeholders have recently completed a Water Use Plan (WUP) for the Wahleach operations. The consultative committee (CC) has recommended several operational changes as part of the WUP, including the provision of minimum flows to satisfy the requirements of its target species, pink salmon. A minimum discharge of 1.1 m$^3$/s is required during the spawning period (15 September through 30 November), and a minimum discharge of 0.6 m$^3$/s is required during all other periods including the incubation period (1 December through 15 March). However, the CC could not address whether instream flows or channel instability were limiting spawning success and fish productivity in Lower Jones Creek. Therefore, the CC approved a comprehensive monitoring program that would assess the effectiveness of the flow regime on fish productivity, as well as assess the channel conditions in Lower Jones Creek as a possible contributor to productivity results. The Terms of Reference (TOR) for the channel stability assessment component were prepared on 25 May 2005 (BC Hydro 2005). The channel stability assessment is scheduled to be carried out in alternate years corresponding to pink salmon runs, starting in 2005-06.
The overall purpose of the lower Jones Creek channel stability assessment is to address two questions:

1) Is channel stability in Lower Jones Creek limiting fish productivity?
2) Is substrate quality in Lower Jones Creek limiting fish productivity?

In order to address the first question, the following hypotheses are to be tested:

- $H_1$: In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to habitat instability in the anadromous reach of lower Jones Creek.

- $H_{1a}$: Fish productivity is not correlated to channel instability as measured by cross-sectional areas of scour and fill in the anadromous reach.

- $H_{1b}$: Fish productivity is not correlated to channel instability as measured by lateral channel migration involving abandonment of spawning habitat in the anadromous reach.

In order to address the second question, the following hypothesis will also be addressed:

- $H_2$: In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

The approach to addressing these hypotheses was outlined in the Terms of Reference. Topographic surveys, site photography and photographic substrate sampling are required at five previously established transect locations along Lower Jones Creek, shown in Figure 2. Survey dates were set to coincide with peak spawning (15 October), midway through incubation (1 January), and end of incubation (15 March). The repeated topographic surveys and site photos will be used to monitor habitat stability. The repeated photographic substrate samples will be used to monitor changes in substrate quality. Comparison of these results with fish productivity data to be collected by other contractors will permit testing of hypotheses $H_1$ and $H_2$. 
respectively. This analysis is based on the assumption that the WUP flow regime is being properly adhered to. This assumption will be checked by referencing streamflow data from the BC Hydro gauging station below the Laidlaw road bridge.

The first year of assessment work, 2005-06, was accepted by nhc in a proposal dated 20 September 2005. Two changes in approach were required as the project proceeded.

1) The TOR had called for an integrated volumetric estimate of net change in bed surface elevation throughout the study reach, based on sequential cross-section surveys. Due to the complexity of bed topography between sections, we recommended discrete analysis of sequential surveys at individual sections instead (see Section 2.1.2 for details). This change was accepted by BC Hydro on 2 November 2005.

2) Problems were encountered with the substrate photo sampling technique due to the hydraulic and turbidity conditions in the study reach. Procedural modifications were made throughout the study period to improve sampling capabilities (see Section 2.2.1 for details).

This report outlines the methodology, results and recommendations of the first year of the program. The results of this report will be used as a baseline for subsequent monitoring which is to occur in 2007-08 and 2009-10.
2. Methodology

2.1 Habitat Stability Monitoring

Previous studies (Macnair 2004) indicate that post-spawning channel migration (instability) is closely related to poor spawning success. Habitat stability monitoring quantifies the magnitude of channel changes during the post-spawning period. Habitat monitoring surveys were scheduled to correspond with various points in the spawning and incubation life cycle phases. The actual dates of channel survey and site photography deviated from the target dates due to weather and flow conditions, and other schedule constraints, as shown in Table 1.

Table 1: Survey schedule for Lower Jones Creek, 2005-06

<table>
<thead>
<tr>
<th>SURVEY</th>
<th>SCHEDULED SURVEY DATES</th>
<th>ACTUAL SURVEY DATES</th>
<th>PINK SALMON LIFE CYCLE PHASE (CORRELATED TO SCHEDULED SURVEY DATES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Channel Survey</td>
<td>15 OCT 2005</td>
<td>25 OCT 2005</td>
<td>PEAK SPAWNING</td>
</tr>
<tr>
<td>2nd Channel Survey</td>
<td>1 JAN 2006</td>
<td>9 FEB 2006</td>
<td>INCUBATION MIDPOINT</td>
</tr>
<tr>
<td>3rd Channel Survey</td>
<td>15 MAR 2006</td>
<td>5 APR 2006</td>
<td>INCUBATION ENDPOINT</td>
</tr>
</tbody>
</table>

2.1.1 Data Collection

nhc visited Lower Jones Creek on 25 October 2005 to identify and re-establish the five cross-sections (shown in Figure 2) and complete the initial topographic survey. Dave Hunter from BC Hydro provided a site orientation. Cross-sections were identified based on information provided to us by BC Hydro (Mikes 2004) and visual recognition of previous markers. New rebar posts were installed and labelled at either end of the five cross-sections. It appears that Section 4 was originally located above the location of the old diversion weir but the channel seems to be degrading since the removal of the structure. A more suitable location was selected approximately 30 m downstream. GPS could not be used to record cross-section locations as vegetation obscured the sky view and limited satellite coverage. Instead, a Nikon C-100 total station was used to survey the cross-section elevations and positions relative to existing survey markers near the pipeline right-of-way and the highway bridge.
Topographic cross-section surveys were completed using slightly different instrumentation each time. The Nikon C-100 total station was used for the first survey on 25 October 2005. The second survey, on 9 February 2006, used a level and stadia rod to survey the cross-sections using a tape to measure distance across the section. Inspections of the survey markers indicated that they were in good condition and had not been disturbed allowing for each transect to be surveyed independently using the markers as control. The final survey was completed on 5 April 2006 using a Nikon NPL-362 total station, again using the survey markers as control.

Cross-section survey detail followed the Terms of Reference, thus including all breaks in slope, wetted edges, and transitions of bed material grain size on the bars and wetted channel bed. Median grain size at each survey point was classified as greater or less than 10 mm size, based on visual estimation.

Nine photo-documentation points (PDPs) were established during the first survey trip. Site photographs were taken from each PDP with same view orientation on each survey date. The site photographs provide useful supplementary information for interpreting topographic survey results. Figure 2 shows the location of the photo-documentation points. The sequential photographs are presented in Appendix A.

2.1.2 Data Analysis

The Terms of Reference specified that the channel survey data were to be used to compute volumetric estimates of net bed material scour and fill for the study reach encompassing the five cross-sections. However, in a memo dated 2 November 2005, nhc advised that such an estimate would be subject to large errors due to the large distances and topographic complexity between cross-sections (nhc 2005). A revised approach was recommended by nhc, and accepted by BC Hydro, in which the data from each cross-section would be analyzed independently to compute cross-sectional areas of scour and fill and lateral channel shifts at each section. These would be considered as five representative samples taken from the study reach, with an assumed positive correlation to reach-wide volumetric changes in bed material topography and planform changes in wetted channel position.
Cross-sectional areas of net scour and fill were computed by comparison of sequential cross-section profiles. Vertical differences in bed elevation of 0.1 m or less were considered to be within the range of survey error due to the irregularity of the channel bed. Net scour or fill were determined to have occurred where the bed elevation dropped or rose, respectively, by greater than 0.1 m between one survey date and the next. Scour and fill polygons were delineated where plotted profiles showed one profile diverging from the previous profile at any location along its length.

Lateral shifts in wetted channel position were computed by comparison of sequential cross-section profiles showing wetted edge positions. A water level was determined for each survey profile by drawing a line connecting the surveyed locations of wetted edge. Before assessing lateral shifts, the flow-related difference in water level between survey dates had to be accounted for. Comparison of stage (water level) at a section having only minor changes in cross-sectional morphology indicates that by increasing the stage of the lower-flow date to match the higher-flow date the corresponding wetted edges (for the higher-flow date) could simply be estimated by extrapolating the higher-flow stage to intersect the bed profile. However, the greater the change in cross-section morphology, the more erroneous this approach becomes. However, as channel changes become more pronounced and the absolute magnitude of channel shifts increases, the need to consider water level differences in determining wetted edge position becomes less significant.

The spatial distribution of spawning density is mapped each year by fisheries contractors and will be used to provide context for the significance of abandoned habitat at each cross-section during each survey interval, based on the lateral shifts in wetted channel position.

2.2 Substrate Quality Monitoring

The abundance of fine sediment in stream substrates is thought to be a key (negative) indicator of fish habitat quality. Many different grain-size limits have been used to define "fine sediment" as it pertains to habitat quality. The Terms of Reference specifies the use of grain-size limits recommended by Tappel and Bjornn (1983): 0.85 mm and 9.5 mm. Photographic substrate samples were collected at dates corresponding to various points in the spawning and incubation life cycle phases to assess changes in fine sediment content. The actual dates of photographic
substrate sampling deviated from the target dates due to weather and flow conditions, and other schedule constraints, as shown in Table 2. These deviations in timing were greater than the topographic survey deviations due to the greater sensitivity of substrate sampling to flow hydraulics and water clarity.

Table 2: Photo sampling schedule for Lower Jones Creek, 2005-06

<table>
<thead>
<tr>
<th>SURVEY</th>
<th>SCHEDULED SAMPLE DATES</th>
<th>ACTUAL SAMPLE DATES</th>
<th>PINK SALMON LIFE CYCLE PHASE (CORRELATED TO SCHEDULED SURVEY DATES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ST SUBSTRATE</td>
<td>15 OCT 2005</td>
<td>8 DEC 2005</td>
<td>PEAK SPAWNING</td>
</tr>
<tr>
<td>SAMPLING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2ND SUBSTRATE</td>
<td>1 JAN 2006</td>
<td>9 FEB 2006</td>
<td>INCUBATION MIDPOINT</td>
</tr>
<tr>
<td>SAMPLING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3RD SUBSTRATE</td>
<td>15 MAR 2006</td>
<td>5 MAY 2006</td>
<td>INCUBATION ENDPOINT</td>
</tr>
<tr>
<td>SAMPLING</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2.1 Data Collection

Photographic substrate samples were collected at the same five transects as the topographic surveys (shown in Figure 2). Three samples were taken on each transect at sample points coinciding with ¼, ½ and ¾ of the measured wetted width at the time of survey. The three samples from each transect were pooled for analysis of a single grain-size distribution at each transect.

Our first attempt to collect photographic substrate samples was made on 25 October 2005, using the same technique that we had applied in the past on Coquitlam River (nhc 2006). This technique allows the surveyor to take photographs of the wetted channel bed in water depths of up to 0.3 m using a regular digital camera and a Plexiglas ring 60 cm in diameter and 35 cm high (Photo 2). Photos are taken vertically by centering the bottom-edge circle of the ring within the top-edge circle of the ring in the field of view. The ring typically calms the water surface to improve photo clarity and provides scale for each photo. However, in rapidly flowing water, turbulence is created by jets of flow entering the ring between the bottom edge and the substrate, reducing visibility. Even at the modest flows of around 1.1 m³/s that were experienced during the 25 October sampling effort, there was enough turbulence in the sampling ring to render this technique ineffective (Photo 3). Furthermore, the water was slightly turbid and depth was also a concern, as most transects experienced depths of greater than
0.3 m at some sample points. Also, using the ring as a scale can be problematic if it is not able to sit flush with the streambed, but rather is perched on a few large protruding stones, as the distance from the ring to the main bed surface changes at each sample location. The ring sampling method was attempted again on 8 December 2005 following the reduction in flow to 0.6 m$^3$/s, with the hope that cooler temperatures and snow cover would also reduce the turbidity levels. While conditions did improve, the ring method was still problematic and the need to modify the sampling device was apparent.

The first revision to the sampling device consisted of a clear Plexiglas box 60 cm in length and width, and 16 cm high, with a closed bottom (Photo 4). This design allowed the box to be pushed slightly under the water surface, providing a clear view into the water like a snorkelling mask. Rather than calming the water as the ring attempted to do, this technique sought to improve clarity by creating a uniform boundary between the water and Plexiglass, thus reducing the spatial variability in light refraction associated with a rough surface. An object of known length needs to be placed on the bed surface for scale. Placement of a smaller scaling object on the bed is less constrained than placement of the ring, thereby reducing the potential for scaling error. This revised technique was applied on 9 February 2006 with a significant improvement in results compared to previous attempts. However, reflection from the Plexiglas bottom obscured large portions of some photo samples (Photo 5). The technique was attempted again on 5 April 2006, but elevated turbidity levels prohibited sample collection.

Further research discovered that an innovative technique was being used in Alaskan stream studies (Whitman et al. 2003). The apparatus developed for this project was a darkened 5-gallon metal can with a Plexiglas bottom, short legs and a camera mount. Adapting this design, nhc constructed a sampling device from a 65-cm length of 36-cm diameter Plexiglas tube (Photo 6). The tube was darkened, fitted with a clear Plexiglas bottom, and mounted with 5-cm long Plexiglas legs. A removable darkened Plexiglas lid was constructed with a camera mount and viewing hole. This design produced a relatively lightweight sampling tube which blocks out all light except for that which filters in from the bottom. Use of a digital camera with manual settings allows photographs to be sampled in various light conditions. As before, an object of known length is placed on the bed for scale. This technique was applied on 5 May 2006 with good results (Photo 7). This technique consistently produces sharp, high resolution images. The length of the sampling tube allows for substrate to be photographed in water deeper than a
metre and with significant turbidity levels. The same scaling object – a 200 mm spike painted orange – was used in May as was used in February, but we found that in some cases one end of the scale would become buried. Future sampling will employ a flat metal rod 30 cm in length and marked at 5 cm intervals.

### 2.2.2 Data Analysis

The abundance of fine sediment on the substrate surface was determined by a grid sampling technique applied to the substrate photographs. Kellerhals and Bray (1971) indicated that analyzing grid samples based on a frequency analysis of size intervals is the only method which can accurately represent a surface layer of a single grain of thickness. The recommended sample size is 50 to 100 b-axis measurements. The dimensions of the grid cells should exceed the largest particles being sampled. This may involve truncating the sample at a specified grain size limit, such that stones exceeding the truncation limit are not counted in the sampling program. This also has the benefit of removing large, less evenly distributed stones from the sampling program, where the presence or absence of one or a few stones may severely skew sample results. For example, Tappel and Bjornn (1983) found that grain sizes in their data set were lognormally distributed below a truncation limit of 25 mm, but deviated from the lognormal distribution when coarser material was included. Truncation of grain-size distributions is acceptable so long as it is always properly reported along with the grain-size results.

We applied a truncation limit of 64 mm to our sampling program, coinciding with the grain-size break between gravel and cobbles. A 64-mm grid was applied to each substrate photo in ArcView GIS. The b-axis (intermediate axis) dimension of the particle underlying each grid node was measured on-screen to the nearest millimetre. The three photos were pooled for each cross-section. On the earlier sample dates, photographic problems limited our sample size. The photographic problems were reduced by the advances in technique, but the final apparatus yielded a smaller field of view and consequently fewer potential sample points. However, the improvements in photo clarity greatly improved our ability to measure particle dimensions, especially in finer sediments.
The substrate grain-size distributions for each transect and sample date were divided into three classes: greater than 9.5 mm, less than 9.5 mm and greater than 1 mm, and less than or equal to 1 mm (approximation of the 0.85 mm value recommended by Tappel and Bjornn (1983)).

2.2.3 Comparison of Photographic and Manual Sampling Techniques

The standard method for estimating the grain-size distribution of the surface layer of substrate is the manual pebble count (Kellerhals and Bray 1971). Standard manual pebble counts are known to be operator-biased toward moderate-sized stones (Bunte and Abt 2001). Most surveyors will underestimate the frequency of finer particles which are tucked into crevices between the larger stones, and will avoid establishing transects which intersect a large number of very coarse stones (i.e. large boulders). For the purposes of a habitat-based substrate study, the former bias is of critical concern as it is the frequency of fine material that is of interest. Biases in coarse particle frequency are eliminated by truncation, as discussed above.

Photographic substrate sampling yields results that are less operator-biased than manual pebble counting in the field, but there is a systematic underestimation in grain-size measurements from photos (Bunte and Abt 2001). Part of a stone may be obscured on the photo, a stone may be laying “on its side” with its b-axis perpendicular to the photo, small stones or fine sediment may be obscured in shadows between larger stones, or particles may be finer than the photo resolution.

In order to assess the effectiveness of the photogrammetric sampling technique, we performed a brief comparison to the standard manual technique during our 5 May 2006 sampling visit. First, we took five photographic samples of the substrate at a location approximately 80 metres downstream of Section 8. Pooled together, the five photographs allowed 109 grain measurements of substrate less than 64 mm in size. Then we randomly selected 100 stones from the area covered by the photos, and measured the length of intermediate axis (or “b-axis”) of each stone, providing 88 samples less than 64 mm in size. Each set of samples was analyzed independently to determine the grain-size distribution, yielding the results shown in Table 3.
Table 3: Comparison of substrate sampling techniques

<table>
<thead>
<tr>
<th>% PERCENT FINER THAN GRAIN SIZE (mm)</th>
<th>MANUAL SAMPLE</th>
<th>PHOTO SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>x ≤ 1</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>1 &lt; x &lt; 9.5</td>
<td>9%</td>
<td>23%</td>
</tr>
<tr>
<td>9.5 ≤ x &lt; 64</td>
<td>91%</td>
<td>74%</td>
</tr>
</tbody>
</table>

The results presented in Table 9 confirm that our photographic sampling technique produces finer grain-size distributions than we would obtain by manual sampling. This can be attributed to both types of error discussed above. The “true” distribution probably lies somewhere between the distributions yielded by each technique. In our field test, we consciously tried to avoid operator bias during our manual sampling, but still found that we rarely selected finer grains tucked between coarser stones. On the other hand, we also observed a stark example of a stone whose grain size would be drastically underestimated by the photo technique (Photo 8). Despite these problems, the best approach is to adopt a technique and apply it consistently, which at least will permit an accurate analysis of changes over time.
3. Results

3.1 Hydrologic Analysis

Hourly discharge and water level data has been provided for the period ranging from 2 October 2005 through 6 May 2006. The data were received from BC Hydro on 29 June 2006, following final QA/QC. Figure 3 presents the hydrograph with the survey and sample dates and required minimum flows noted. Mean discharge, during each of the channel surveys and substrate sample collections, is presented below:

- 25 October 2005: 0.8 m³/s.
- 8 December 2005: 0.6 m³/s.
- 9 February 2006: 1.8 m³/s.
- 5 April 2006: 1.6 m³/s.
- 5 May 2006: 1.5 m³/s.

The current Water Use Plan indicates that a minimum flow of 1.1 m³/s is required during the spawning period, but this flow was not met during four periods in October 2005. These periods of inadequate flow are shown in Table 4. The non-compliant flows occurred during a problem with the Wahleach Lake siphon that augments flow in Lower Jones Creek.

Table 4: Periods of inadequate flow, 2005-06

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>AVERAGE FLOW (m³/s)</th>
<th>MINIMUM FLOW (m³/s)</th>
<th>NUMBER OF HOURS AT MINIMUM FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Oct, 09:00 – 6 Oct, 17:00</td>
<td>0.9</td>
<td>0.6</td>
<td>4</td>
</tr>
<tr>
<td>23 Oct, 02:00 – 23 Oct, 19:00</td>
<td>1.0</td>
<td>0.9</td>
<td>2</td>
</tr>
<tr>
<td>23 Oct, 21:00 – 26 Oct, 03:00</td>
<td>0.9</td>
<td>0.7</td>
<td>4</td>
</tr>
<tr>
<td>26 Oct, 06:00 – 27 Oct, 06:00</td>
<td>0.8</td>
<td>0.7</td>
<td>5</td>
</tr>
</tbody>
</table>

The minimum flow of 0.6 m³/s required during the incubation period was met at all times. In all cases of inadequate spawning period flows, the duration of minimum values was brief and the
magnitude of flow did not drop below the minimum flows required for the incubation period. Therefore, we conclude that these inadequacies in flow will not significantly complicate our testing of habitat stability and substrate quality hypotheses.

The occurrence of high flood flows is of interest in interpreting changes in channel morphology and substrate quality. The peak flow for the study period occurred on 17 October 2005, eight days before the initial survey date. The maximum instantaneous discharge on this day was 19.9 m$^3$/s, which dwarfs the second highest flow of 11.3 m$^3$/s on 7 January 2006. Four other flood events with peak discharges of 5 to 10 m$^3$/s occurred from November through January. During the period between the February and April surveys, the maximum flow of only 3.7 m$^3$/s occurred on 27 February 2006. Flows were slightly higher later in April due to snowmelt, with maximum values in the 4 to 5 m$^3$/s range, still well below the peak values observed during the autumn and early winter.

### 3.2 Habitat Stability Monitoring

The results of the three sets of channel surveys are shown in Figure 4. Surveyed profiles have been overlaid for each of the three dates using the cross-section benchmarks as vertical and horizontal control. All distances are plotted based on distance from the left bank marker, as established on 25 October 2005. Observed transitions between substrate classes and location of the wetted edge are shown on Figure 4 as linear graphs located above the plotted cross-sections. Measured changes in cross-sectional area are shown in Table 5. The values in Table 5 reflect totals of scour and fill for each period, not net values (i.e. scour minus fill) as may have been assumed by the fact that one period experienced no fill while the other period experienced no scour. There were no observed changes in the position of the wetted channel that could be detected above the minor variations in wetted edge position associated with variations in flow. Therefore, there was no detectable abandonment of spawning habitat due to channel migration.

Our cross-section 4 lies within fisheries monitoring section S2; our cross-sections 6, 8, 9, and 10 lie within the fisheries monitoring section S3 (Greenbank and Macnair 2006). In Autumn 2005, the spawning distribution among the five monitoring sections in Lower Jones and Lorenzetta Creeks saw 11% in S2 and 20% in S3 for pink salmon, and 20% in S2 and 17% in S3 for chum salmon.
Overall, the channel changes observed in Lower Jones Creek during the study period were relatively small compared to the anecdotal and visual evidence of past channel activity. Where changes in bed elevation were observed, they were typically in the range of 0.1 to 0.2 m at one or two survey points, which is barely above the level of survey detectability. In the first period – October 2005 through February 2006 – minor scour was observed at three of the five sections, likely resulting from the occurrence of several moderate flow events during the period. In the second period – February through April 2006 – minor fill was observed at four of the five sections, likely resulting from the occurrence of smaller flow events during this period. Apparently, the increased transport capability of larger flows events outweighed the increased sediment load of those events in terms of affecting channel morphology, at least for the range of conditions observed during the study period. In larger flood events, such as the event immediately preceding our study period, this may not be the case. Fish productivity personnel noted some lateral shifting in channel position in the early autumn prior to our initial survey, but no shifting thereafter (Greenbank and Macnair 2006). Deposition during the early October event may have set the stage for compensating scour during subsequent moderate events in November through January. Bioturbation by spawning fish and seasonal changes in hillslope erosion processes may also have played a minor role in the observed temporal trends.

Site-specific discussions of observed channel changes are discussed below, with reference to site photographs taken from the photo-documentation points (PDPs). The PDP photographs are presented in Appendix A.
3.2.1 Section 4

Section 4 is located immediately downstream from a recently lowered weir. The creek channel below the weir is subject to seasonal backwater from the Fraser River during the late spring freshet when bed filling of up to a metre or more can occur. The creek was free-flowing throughout our study period, and also would have been so during the early October flood event in Jones Creek.

Two distinct channels were consistently surveyed over the first year of monitoring. The left channel sits approximately a half metre higher than the right channel and is separated by a mid-channel bar, 4 m in width. Scour of 0.57 m² was observed in the deeper right channel between October 2005 and February 2006, followed by a similar quantity of fill (0.49 m²) between February and April 2006. The overall channel pattern seems to be stable as indicated by the low variability in surveyed wetted edge over the survey year. This section is less likely to experience sediment deposition than Sections 6 and 8 upstream (except during periods of Fraser River backwater) because the channel here is narrower and faster-flowing.

3.2.2 Section 6

Section 6, located upstream from the weir, is the widest cross-section and experienced the greatest morphologic change of the surveyed sections, primarily between October 2005 and February 2006. Total scour of 1.69 m² was observed during that period. Maximum scour depths of 0.2 to 0.3 m occurred in the main channel toward the left bank, and 0.1 m near the low right bank. This secondary channel near the right bank appeared to gaining a greater share of the total flow in February, but comparisons were complicated by differences in flow conditions. A distinct fining of the surface material in the channel and bar along the right bank between October and February was observed during the topographic survey, despite the lack of infilling measured during the same period, most likely indicating a thin layer of fine sediment deposition over gravel. The site photographs taken from PDPs 3 and 4 indicate that a piece of large woody debris (LWD) had settled on the right bar a short distance upstream from Section 6 sometime between October and February.

A survey error occurred during the survey of 9 February 2006. A newly discovered endpoint marker, previously established by others but not seen by nhc on 25 October 2005, was used for
survey control instead of the benchmark established in October. The February survey data was corrected based on a vertical shift using the top of a surveyed concrete block as reference.

### 3.2.3 Section 8

Section 8 is nearly as wide as Section 6 but experienced little change in channel morphology during the study period, including no scour or fill during the October 2005 to February 2006 period. Minor fill of 0.32 m$^2$ was observed between February and April 2006 in a minor secondary channel along the right bank that is active only during high flow events (PDP 7). However, fining of the bar surface was observed during both periods, with an increasing extent of material finer than 10 mm. The extent of this material had expanded into the wetted channel by the time of the April survey. The area covered by fine material did not show any detectable change in elevation throughout the study period, most likely indicating a thin layer of fine sediment deposition over gravel. The changes in substrate character are not easily discernible in the site photographs (PDPs 5, 6 and 7).

### 3.2.4 Sections 9 and 10

Sections 9 and 10 are located in the incised portion of channel on the upper fan (PDPs 8 and 9). Apparent differences in profiles on the steep high banks are more likely due to positional survey errors than bank erosion, and therefore have not been included in our channel change results. The problems arise because of the high banks, such that the endpoint markers are not visible from the channel. During the October survey, the rod person estimated the transect alignment based on the benchmark locations. During the February survey, we strung a tape across the channel, but high winds caused the tape to bulge off-line. During the April survey, the rod person estimated the transect alignment based on the benchmark locations following the methods used during the October survey. Positional errors occurred in all cases, due to misalignment of the tape measure or the rod person resulting in the plotting of stable banks at slightly different distances for each of the three survey dates for a given cross section. In order to minimize this positional error, the total station should be set up on one of the cross-section benchmarks with its view field fixed on the prism located at the opposite benchmark. The total station operator should direct the rod person to this fixed alignment resulting in completely similar cross-sections every time.
No scour or fill was observed on the channel bed at Section 9. Minor scour (0.20 m$^2$) and fill (0.22 m$^2$) were observed at Section 10. These may be related to the positional survey errors discussed above. Regardless, these values are low and not particularly significant.

### 3.3 Substrate Quality Monitoring

The collection of photographic substrate samples is summarized in Table 6. Sample points across the transect are labelled “L”, “M”, and “R”, indicating positions at ¼, ½ and ¾ of the wetted channel width relative to the left wetted edge. Images were not successfully captured at Sections 4 and 6, or at sample point L on Section 9, during the 8 December 2005 visit due to flow conditions and the limitations of the apparatus being used at that time (as discussed earlier). The number of grain-size measurements made on each photo sample is presented, along with the relative percentage (in parentheses) for the pooled sample points at each section on each date.

**Table 6: Substrate sample distribution – Year 1**

<table>
<thead>
<tr>
<th>CROSS SECTION</th>
<th>8 DEC 2005</th>
<th>9 FEB 2006</th>
<th>5 MAY 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>M</td>
<td>R</td>
</tr>
<tr>
<td>10</td>
<td>97 (34%)</td>
<td>98 (34%)</td>
<td>91 (32%)</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>96 (49%)</td>
<td>99 (51%)</td>
</tr>
<tr>
<td>8</td>
<td>78 (29%)</td>
<td>84 (31%)</td>
<td>106 (40%)</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The distribution indicates that in most cases, where samples were taken at all three points, the sample measurements at each section are distributed fairly evenly between the three photo points (ie. near 33.3% of measurements at each photo point). The fairly even distribution of samples minimizes sample bias due to location along each transect. It is expected that, in general, fines will be distributed in greater amounts along the edges of the channel where flow depth and velocity are lowest.
Grain-size distributions for each of the cross-sections and sample dates are presented in Figures 5 through 9. The fraction of measured grains falling within the three indicative size ranges – greater than 9.5 mm and less than 64 mm, less than 9.5 mm and greater than 1 mm, and less than or equal to 1 mm – are presented in Table 7. Changes in grain-size distributions at each section between sample dates are presented in Table 8. The values are differences in the percentage values between consecutive dates as presented in Table 7. A discussion of changes at each cross-section follows.

### Table 7: Measured substrate grain size – Year 1

<table>
<thead>
<tr>
<th>CROSS SECTION</th>
<th>PERCENTAGE OF MEASURED GRAINS IN SIZE RANGE (mm)</th>
<th>8 DEC 2005</th>
<th>9 FEB 2006</th>
<th>5 MAY 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x ≤ 1</td>
<td>1 &lt; x &lt; 9.5</td>
<td>9.5 ≤ x &lt; 64</td>
<td>x ≤ 1</td>
</tr>
<tr>
<td>10</td>
<td>0%</td>
<td>15%</td>
<td>85%</td>
<td>0%</td>
</tr>
<tr>
<td>9</td>
<td>0%</td>
<td>14%</td>
<td>86%</td>
<td>0%</td>
</tr>
<tr>
<td>8</td>
<td>6%</td>
<td>7%</td>
<td>87%</td>
<td>9%</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1%</td>
</tr>
</tbody>
</table>

### Table 8: Calculated change in substrate grain size – Year 1

<table>
<thead>
<tr>
<th>CROSS SECTION</th>
<th>CHANGE IN % PERCENT FINER THAN GRAIN SIZE (mm)</th>
<th>DEC 2005 - FEB 2006</th>
<th>FEB 2006 - MAY 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x ≤ 1</td>
<td>1 &lt; x &lt; 9.5</td>
<td>9.5 ≤ x &lt; 64</td>
</tr>
<tr>
<td>10</td>
<td>0%</td>
<td>-20%</td>
<td>0%</td>
</tr>
<tr>
<td>9</td>
<td>0%</td>
<td>-18%</td>
<td>0%</td>
</tr>
<tr>
<td>8</td>
<td>3%</td>
<td>-14%</td>
<td>33%</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>6%</td>
</tr>
</tbody>
</table>

### 3.3.1 Section 4

A slight increase in fine sediment less than 1 mm in size was observed between February and May 2006 at Section 4. The fraction of measured grains in this size range increased from 1% to 7%. This coincides approximately with the minor channel fill that was observed to have occurred during the February to April survey period.
3.3.2 **Section 6**

A slight increase in fine gravels, 1 to 9.5 mm in size, was observed between February and May 2006 at Section 6. The fraction of measured grains in this size range increased from 10% to 17%. This coincides approximately with the minor channel fill that was observed to have occurred during the February to April survey period.

3.3.3 **Section 8**

The greatest change in substrate grain-size distribution occurred at Section 8, despite its morphologic stability. In December 2005, the sampled bed material was dominated by coarse grains greater than 9.5 mm in size (87%), with 6% of grains less than 1 mm. In February, the content of fine sediment, less than 1 mm in size, had increased from 6% to 9% and the content of fine gravels, 1 to 9.5 mm in size, had increased from 7% to 18%, with a corresponding decrease in coarser grain content from 87% to 74%. In May, a dramatic increase in fine sediment fraction (less than 1 mm) was observed: an increase from 9% to 42%. This corresponds with our survey observations of an expanding extent of fine sediment cover on the bar extending into the wetted channel. The fraction of material greater than 9.5 mm was only 48% as compared to 87% in October. Photos 9 to 11 show the influx of fines and qualitatively illustrates the reduction in suitable substrate for salmon habitat.

3.3.4 **Sections 9 and 10**

Sections 9 and 10 are steeper, narrower and faster flowing than the other cross-sections. No fine sediment less than 1 mm in size was observed on any date at either section. The fractions of fine gravels, 1 to 9.5 mm in size, were similar at the two sections, and followed similar trends in the first part of the study period. Fine gravel content was 14% to 15% in December, increasing to 33% to 34% in February. Subsequently, the fine gravel content at Section 9 increased further from 33% to 37% in May, whereas it decreased from 34% to 28% in May at Section 10.
4. Conclusions and Recommendations

4.1 Monitoring Conclusions

4.1.1 Habitat Stability

Overall, the channel changes observed in Lower Jones Creek during the study period were relatively small compared to the anecdotal and visual evidence of past channel activity. Where changes in bed elevation were observed, they were typically in the range of 0.1 to 0.2 m at one or two survey points, which is barely above the level of survey detectability. In the first period – October 2005 through February 2006 – minor scour was observed at three of the five sections, likely resulting from the occurrence of several moderate flow events during the period. In the second period – February through April 2006 – minor fill was observed at four of the five sections, likely resulting from the occurrence of smaller flow events during this period. There were no observed changes in the position of the wetted channel that could be detected above the minor variations in wetted edge position associated with variations in flow. Therefore, there was no detectable abandonment of spawning habitat due to channel migration.

At Section 6, there was a distinct fining of the bar and secondary-channel surface material between October 2005 and February 2006. A more extensive fining of bar surface material was observed at Section 8 throughout the study period (October 2005 through April 2006), with the area of fine material extending into the wetted channel. At both sections, negligible fill thicknesses were observed in conjunction with the substrate fining, most likely indicating a thin layer of fine sediment deposition over gravel.

4.1.2 Substrate Quality

The greatest changes in substrate grain-size distributions, as sampled photographically within the wetted channel occurred at Section 8. This corresponds with our survey observations of an expanding extent of fine sediment cover on the bar extending into the wetted channel. The content of fine gravels, 1 to 9.5 mm in size, increased from 7 % to 18%, between December and February. More dramatically, the content of fine sediment less than 1 mm in size increased from 6% in December and February to 42% in May; although this trend may be exaggerated
because of improvements in the quality of photo samples and a decrease in the sample size over time.

At Sections 9 and 10, the fractions of fine gravels increased from 14% and 15%, respectively, in December to 33% and 34%, respectively, in February. Subsequently, the fine gravel content at Section 9 increased further from 33% to 37% in May, whereas it decreased from 34% to 28% in May at Section 10. Changes in substrate composition were less marked at Sections 4 and 6.

4.2 Recommendations for Methodological Improvements

4.2.1 Habitat Stability Monitoring

We recommend re-surveying the cross-section endpoint markers and establishing additional control to ensure that cross-section endpoints can be re-established if the markers are destroyed prior to the next survey season (2007-08).

At each section, the total station should be set up over one of the endpoint markers and sighted on the rod person standing at the opposite endpoint marker. Once the rod is sighted, the horizontal mechanism should be locked and the total station operator shall instruct the rod person on the correct alignment of the cross-section. This will reduce positional deviation from the cross-section alignment and will improve comparison of sections over time.

If the independent analysis of cross-sections contained herein is deemed inadequate for the purposes of the WUP monitoring program, a number of steps can be taken to provide reach-wide composite results. Firstly, topographic breaklines could be surveyed between cross-sections to aid in the calculation of volumetric bed level changes. The channel is particularly wide and complex between Sections 6 and 8. Additional topographic data would be needed in that area in particular before any volumetric estimates could be attempted. Secondly, additional photo-documentation points (PDP) could be established to aid in the analysis of wetted channel migration. An even better method would be to obtain periodic low-level areal photography.
4.2.2 Substrate Quality Monitoring

The modified photographic sampling apparatus represents a considerable improvement to our previous substrate sampling technique. However, the field of view is significantly smaller than our previous sampling devices, prompting the recommendation that several non-overlapping photographs should be taken at each photo sample point to provide larger sample sizes.

The scaling object used for photographic sampling – a 200 mm spike painted orange – occasionally became partially buried. Future sampling should employ a flat metal rod, 30 cm in length and marked at 5 cm intervals.
5. References


FIGURES
NOTE:
1) Watershed boundaries drawn based on 1:50,000 N.T.S. mapping.
2) LANDSAT 7 orthoimage used for background.
NOTES:
1) TYPE 'A' SURVEY = CROSS SECTION SURVEY
2) TYPE 'B' SURVEY = SUBSTRATE PHOTO SURVEY

SURVEY DATE       FLOW (cms)
25 OCT, 2005      0.6
8 DEC, 2005       0.8
9 FEB, 2006       1.0
5 APR, 2006       1.5
5 MAY, 2006       1.5
NOTES:
1) Substrate size distribution based on GIS analysis of photo samples.
2) Samples measured on a 64 mm regular grid and recorded into a database.
3) Sample population limited to grain sizes less than 64 mm diameter.
4) Distribution based on pooling of three samples at each section.

WAHLEACH WATER USE PLAN MONITORING

Substrate grain-size distributions
Section 4

northwest hydraulic consultants

FIGURE 5
NOTES:
1) Substrate size distribution based on GIS analysis of photo samples.
2) Samples measured on a 94 mm regular grid and recorded into a database.
3) Sample population limited to grain sizes less than 94 mm diameter.
4) Distribution based on pooling of three samples at each section.
Substrate grain-size distributions

Section 8

NOTES:
1) SUBSTRATE SIZE DISTRIBUTION BASED ON GIS ANALYSIS OF PHOTO SAMPLES.
2) SAMPLES MEASURED ON A 64 mm REGULAR GRID AND RECORDED INTO A DATABASE.
3) SAMPLE POPULATION LIMITED TO GRAIN SIZES LESS THAN 64 mm DIAMETER.
4) DISTRIBUTION BASED ON POOLING OF THREE SAMPLES AT EACH SECTION.
NOTES:
1) SUBSTRATE SIZE DISTRIBUTION BASED ON GIS ANALYSIS OF PHOTO SAMPLES.
2) SAMPLES MEASURED ON A 64 mm REGULAR GRID AND RECORDED INTO A DATABASE.
3) SAMPLE POPULATION LIMITED TO GRAIN SIZES LESS THAN 64 mm DIAMETER.
4) DISTRIBUTION BASED ON POOLING OF THREE SAMPLES AT EACH SECTION.
NOTES:
1) Substrate size distribution based on GIS analysis of photo samples.
2) Samples measured on a 94 mm regular grid and recorded into a database.
3) Sample population limited to grain sizes less than 94 mm diameter.
4) Distribution based on pooling of three samples at each section.

WAHLEACH WATER USE PLAN MONITORING

Substrate grain-size distributions
Section 10

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PHOTOGRAPHS
PHOTO 1
Exposed tree roots on the right bank (looking downstream) at Section 9.

PHOTO 2
Photo sampling using the Plexiglas ring. Note the calm water condition.
PHOTO 3
Photo sample using the Plexiglas ring. This sample is useless because of turbulent and turbid water conditions.

PHOTO 4
Photo sampling using the Plexiglas box. Note the flat bottom produces a clear view through the turbulent water. A 200 mm long orange spike typically used for scale with this device is not shown.
PHOTO 5
Photo sample using the Plexiglas box. This sample is useless because of the reflections cast by the Plexiglas bottom.

PHOTO 6
Photo sampling apparatus used in May 2006. The Plexiglas tube has a mounting device for the camera and a viewing hole. The bottom is clear. Note the clear Plexiglas feet which allow light to enter the bottom.
PHOTO 7
Photo sample using the Plexiglas tube. This sample provides a clear, high resolution photograph in turbulent and turbid water. Note the 200 mm long orange spike used for scale.

PHOTO 8
Notice the rusty colouring on the lower right portion of the stone. This rusty coloured portion of the stone was exposed and the remaining portion was buried. This stone size would be underestimated using a photo sampling technique.
PHOTO 9
Sample located at the photo sampling point R at Section 8. Photo dated 8 Dec 2005.

PHOTO 10
Sample located at the photo sampling point R at Section 8. Photo dated 9 Feb 2006.
PHOTO 11
Sample located at the photo sampling point R at Section 8. Photo dated 5 May 2006.
APPENDIX A

Photographs Taken at Photo-Documentation Points (PDPs)
PHOTO POINT 1
LOOKING UPSTREAM TOWARD SECTION 4

OCT 2005

FEB 2006

APR 2006

Wahleach WUP Monitoring – Lower Jones Creek Channel Stability
BC Hydro – Final Report, December 2006
PHOTO POINT 2
LOOKING
DOWNSTREAM
TOWARD
SECTION 4
PHOTO POINT 3
LOOKING UPSTREAM TOWARD SECTION 6

OCT 2005

FEB 2006

APR 2006
PHOTO POINT 4
LOOKING
DOWNSTREAM
TOWARD SECTION 6

OCT 2005

FEB 2006

APR 2006
PHOTO POINT 5
LOOKING UPSTREAM FROM SECTION 8

OCT 2005

FEB 2006

APR 2006
PHOTO POINT 6
LOOKING
DOWNSTREAM
TOWARD SECTION 8

OCT 2005

FEB 2006

APR 2006

Wahleach WUP Monitoring – Lower Jones Creek Channel Stability
BC Hydro – Final Report, December 2006
PHOTO POINT 7
LOOKING
DOWNSTREAM
TOWARD SECTION 8

OCT 2005

FEB 2006

APR 2006
PHOTO POINT 8
LOOKING UPSTREAM
FROM SECTION 9
TOWARD SECTION 10

OCT 2005

FEB 2006

APR 2006
PHOTO POINT 9
LOOKING
DOWNSTREAM
TOWARD
SECTION 9

OCT 2005

FEB 2006

APR 2006