Coquitlam Water Use Plan

Lower Coquitlam River Substrate Quality Assessment

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Northwest Hydraulic Consultants
COQUITLAM – BUNTZEN WATER USE PLAN MONITORING PROGRAM
LOWER COQUITLAM RIVER SUBSTRATE QUALITY ASSESSMENT
2007 ANNUAL DATA REPORT

Final Report
March 2008

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EXECUTIVE SUMMARY

Under the Coquitlam-Buntzen Water Use Plan (WUP), substrate maintenance flow releases (or “flushing” flows) have been recommended for the lower Coquitlam River to reduce the quantity of sediment less than 10 mm diameter from the upper 10 to 20 cm depth of substrate. The flushing flows are intended to improve fish productivity by improving substrate conditions for egg incubation and juvenile rearing, both of which are currently impaired by the abundance of fine sediment in the channel bed. The flushing flows are to be achieved opportunistically with annual releases of 30 to 50 m$^3$/s from the dam, for three to five days in duration, that coincide with high tributary inflows to produce total flows of 70 to 100 m$^3$/s. The largest tributary, Or Creek, is thought to be the largest source of sediment to lower Coquitlam River, so prolonged flushing flow releases will likely be required to ensure that sediment delivered during high inflow events travels far downstream. Gravel mines along the west side of the river, downstream of Or Creek, also contribute potentially significant quantities of fine sediment to the river. Periodic turbidity measurements in 2007 reveal that gravel mining operations increase turbidity, but there are no concurrent samples of total suspended solids which are needed to estimate the suspended sediment load.

Substrate quality assessments in lower Coquitlam River are intended to provide a basis for evaluating the effectiveness of flushing flows at reducing fine sediment abundance and improving fish productivity. If the flushing flows are found to be effective, then a further goal will be to optimize the flushing flow criteria. The substrate surface is to be sampled photographically at 10 sites below Coquitlam Dam three times per year at times coinciding with spawning (15 October), mid-incubation (15 January) and end of emergence (1 May). The subsurface is to be sampled by the extraction and sieving of bulk samples once per year (1 May). Two grain-size classes are used to characterize substrate composition: less than 1 mm, and 1 to 10 mm. Sampling is truncated at 64 mm to avoid bias introduced by large stones which could occupy an entire sample site. Ideally, subsurface samples would be collected at these same sites, but for reasons of practicality subsurface sampling has been restricted to gravel bars adjacent to the two most downstream sites and a single site upstream.
This report presents the results of the second year of substrate assessment under the Coquitlam-Buntzen WUP. Surface samples were collected in January and May 2007, while subsurface samples were collected in May and September. Attempts to collect photogrammetric surface samples in October were not successful due to elevated turbidity levels caused by a natural landslide below the dam. Turbidity levels remained high through to the end of the year. Pebble counts were additionally collected at the site where bulk samples were taken. Sampling in both January and May reflects potential changes in substrate quality following the passage of flushing flow events in November 2006 and March 2007. In January 2007, the fraction of surface material less than 1 mm in diameter ranged from 1 to 12%, generally higher than in September 2006, when this fraction did not exceed 3% at any site. The changes to May show a slightly higher composition of sand at many sites, but there is no consistent pattern that reflects the effects of the flushing flows. Since material smaller than 1 mm can be introduced from smaller flows and gravel mining operations, the fraction of this material on the surface appears to be independent of flushing flows.

Surface material in the 1 to 10 mm size class is more abundant at all sites with the highest levels in Reach 2. The fraction of surface material in the 1 to 10 mm size class was found to generally decrease between September 2006 and January 2007 at several sites, and again generally decreased between January and May, following a second flushing flow. These results suggest that the flushing flows are an effective means of reducing the content of fine sand and gravel in the substrate, hence are beneficial to improving the quality of fish habitat. However, longer-term monitoring is required to confirm whether this relation between substrate quality and maintenance flows continues to be maintained. The material removed from upstream reaches appears to have deposited in the lower part of reach 1 where the surface and subsurface distributions became finer. Bulk samples were collected in the upper part of reach 2, but this site was not previously sampled using this approach, so it is not yet possible to conclude that the flushing flows have been successful at reducing the fine material deposited in the subsurface substrate, as has been observed on the surface.
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1. Introduction

1.1 Background

Coquitlam River flows into Fraser River about 30 km east of Vancouver, BC (Figure 1). BC Hydro and Power Authority (BC Hydro) owns and operates the Coquitlam-Buntzen Hydroelectric Project, located about 17 km upstream from the mouth of Coquitlam River. The project consists of dams on Coquitlam and Buntzen Reservoirs, a diversion tunnel from Coquitlam Reservoir to Buntzen Reservoir, and two generating stations on Indian Arm. Construction of Coquitlam Dam began in 1910 and the project was initially brought into service in 1914. Coquitlam Reservoir is also used by Metro Vancouver (formerly GVRD) as a source of potable water for the region.

Previous studies (nhc 2001, nhc 2006) have documented the existing channel morphology and substrate (bed sediment) conditions in lower Coquitlam River (below Coquitlam Dam). Overall, the channel is much narrower than it was prior to regulation and the coarse, formerly mobile substrate is now rarely mobilized and has become embedded with fine sediment. The altered substrate, in particular, is thought to provide degraded spawning, incubation and rearing habitat for salmonids. Excess fine sediment in substrates can reduce the rate of water flow through the substrate and restrict the movement of emergent salmonids. nhc (2001) recommended “flushing” flow releases from the Coquitlam Dam that would be required to improve or maintain channel and substrate conditions. Channel maintenance flows are large releases that result in
channel enlargement, general bed and bar mobilization, and removal of riparian vegetation. Substrate maintenance flows are smaller releases designed to remove fine sediment from the surface layer of the substrate without causing major channel changes. As part of the Coquitlam-Buntzen Water Use Plan (WUP), the consultative committee endorsed an opportunistic high-magnitude, short-term flushing flow for substrate maintenance. This flushing flow consists of a targeted annual release of 30 to 50 m$^3$/s for three to five days in duration that coincides with high inflows from Or Creek to produce a total flow of 70 to 100 m$^3$/s (BC Hydro 2005). Previous studies have indicated that flows of this magnitude are expected to remove up to 5000 m$^3$ of sand from the near-surface substrate layer to a depth of 20 to 30 cm if they are sustained for several days. In addition, the flushing flows are thought to be effective at recruiting new gravel sources through erosion, and routing this material downstream.

In 2005, BC Hydro commenced a 12-year monitoring program of flushing-flow effectiveness under the Coquitlam-Buntzen WUP. The key question to be addressed is whether the recommended flushing flows would result in improved substrate conditions, hence increased fish productivity in lower Coquitlam River. If the results are found to be positive, a secondary objective of the monitoring program would be to optimize the flushing flow criteria. This report provides substrate monitoring results for 2007 – the second year of data collection under the current monitoring program – and provides a preliminary comparison with 2006 results. The substrate monitoring program was initiated in 2000, and a 2003 pilot project attempted to refine data collection techniques for substrate monitoring and provide an initial evaluation of flushing flow effectiveness (nhc, 2006).

A number of program modifications have been identified in the earlier stages of the monitoring program, including a reduction in the number of sampling sites with increased sampling at the retained sites, new bulk sampling on an upstream bar, and difficulties of bulk sampling in the wetted channel. Several of these recommendations have been adopted and incorporated into the monitoring for year three of the program, and are identified in an addendum to the original monitor. If the changes prove successful, it is expected that they will be maintained at least through year five. Future reporting will also include the results of turbidity monitoring and suspended sediment sampling in an attempt to better define the impacts of gravel mining operations on substrate conditions.
1.2 Objectives and Approach

The substrate monitoring program in the lower Coquitlam River will aim to test the following specific alternate hypotheses:

- **H₁**: Substrate composition is not significantly affected by flushing flows that meet criteria defined during the Coquitlam-Buntzen WUP project.

- **H₂**: Fish productivity is not correlated to substrate composition as measured by surface areal fraction of fines in representative channel locations on lower Coquitlam River.
  
  - **H₂a**: Egg-to-fry survival is not correlated to substrate composition.
  - **H₂b**: Smolt production is not correlated to substrate composition.
  - **H₂c**: The areal fraction of fines is not less than the bio-standard thresholds identified in relevant literature.

If **H₁** is refuted, then the following additional hypotheses are to be tested:

- **H₃**: There is no correlation between substrate composition and flushing flow mechanism (regulated or unregulated).

- **H₄**: There is no correlation between substrate composition and duration and/or magnitude of flushing flow.

It is understood that the adopted sampling protocols may be inadequate to properly test these hypotheses until sufficient data have been collected, so the acceptance or rejection of any should be considered preliminary and subject to change.

Substrate composition is quantified by the relative fraction of bed material falling within the less than 0.85 mm and 0.85 to 9.5 mm grain-size classes as specified by Tappel and Bjornn (1983). These limits are rounded off to 1mm and 10 mm to reflect the level of measurement precision based on our sampling procedures. We have adopted two main techniques to measure grain-size composition of the bed material. For the surface layer, we used a photogrammetric
technique in which the river bed was photographed and grain size (b-axis) was measured from scaled photographs using Geographic Information system (GIS) software. For the subsurface, we excavated and sieved bulk samples on exposed bars. Surface samples were collected at 10 transects along lower Coquitlam River. Subsurface samples – which are far more onerous to collect, especially in coarse material and/or within the wetted channel – were collected at two sites near the downstream limit of the study area and at one site near Gallette Avenue. An additional effort to collect subsurface samples using a freeze-core technique at the Gallette Avenue site was also attempted. The number and location of sample sites was specified by BC Hydro to represent spawning and rearing habitat according to previous assessments (BC Hydro 2005). In order to address the uncertainty associated with using the surface analysis as an indicator of substrate quality (i.e. the sampling methods correlate reasonably well), the following additional hypothesis is to be tested annually:

- $H_5$: Substrate quality as described by surface areal photogrammetry is not significantly correlated to substrate quality as described by volumetric bulk sieve tests.

The schedule for surface sample collection, specified by BC Hydro, was designed to coincide with the spawning, incubation and rearing phases for salmon in lower Coquitlam River, which includes the weeks of:

- 15 October: start of spawning;
- 15 January: mid-incubation; and
- 1 May: end of emergence.

It should be recognized that poor weather conditions, including heavy rain or snow, high water levels and elevated turbidity are amongst the uncontrollable factors that make sampling on target dates problematic. However, provided there are no very large flows between the sampling target date, and the actual sampling date, the substrate morphology would not change appreciably. Subsurface samples were specified to be collected only once per year during late summer. Each year, the substrate results are to be interpreted in light of the annual hydrograph (recorded by Water Survey of Canada), which is typically dominated by large autumn and winter rainstorm-runoff events, and turbidity and suspended sediment results.
recorded by the City of Coquitlam if these data are available. Comparisons of substrate results and fish productivity results will be made every third year, starting in 2009.

1.3 The 2007 Sampling Program

This 2007 program was commenced on January 31, two weeks past the mid-point of the incubation program. Weather and water conditions were both clear on this date (Photo 1). The next set of sampling was completed on May 16, two weeks after the end of the emergence period, also during favourable weather and water conditions. Two of the sites (PSS 1 and PSS 15) were not photographed until the end of the month. Wolman (surface) samples and bulk (subsurface) samples were also collected at the end of May. An attempt was made to collect freeze-core substrate samples on September 12 at three sites, but the program was not successful due to the coarseness of the substrate that prevented sampler penetration. A week later, an additional bulk sample was collected at PSS 7 near Gallette Avenue (the site was nearly submerged in May). A final visit was made on October 26, during the spawning period, but photos could only be collected at a single site because of a natural landslide near the dam which created highly turbid water conditions. The slide has not yet been successfully mitigated, and continues to elevate river turbidity except during prolonged dry or cold periods. Since the spawning period sampling is incomplete, the results presented in this report do not constitute a complete annual cycle of habitat conditions. A summary of the 2007 program in comparison to the targets set forth in the WUP is provided in Table 1.
2. Lower Coquitlam River

2.1 Physiography and Surficial Materials

Coquitlam River drains an area of roughly 270 km\(^2\) in the southern Coast Mountains (Figure 1). The watershed can be divided into two sections above and below Coquitlam Dam. The upper watershed covers an area of 193 km\(^2\), with elevations ranging from 184 m at Coquitlam Lake to 1,740 m at Obelisk Peak. The lower watershed drains an area of 79 km\(^2\) and flows within a narrow valley for approximately 6 km downstream of the dam (near Gallette Avenue) and is bounded by mountains ranging to 1,000 m in elevation. Further downstream, the valley widens out onto the Fraser River lowland and the river is largely confined by dykes.

The contemporary river has incised through a thick sequence of sediments deposited during late Quaternary glacial advances (Armstrong, 1990). These sediments include glaciofluvial outwash sands and gravels, deltaic silts and fine sands, glaciomarine and glaciolacustrine clays and silts, and bouldery glacial till. Downstream of Gallette Avenue to near Lougheed Highway, the river becomes less confined and flows through glacial till overlain by stony glaciomarine clays and sandy beach deposits deposited during elevated sea-levels at the time of the most recent deglaciation. Further downstream, the river flows across post-glacial alluvial fan deposits and Fraser River floodplain deposits.

Sediments in the river are largely derived from tributary inputs, mass wasting of glaciolacustrine deposits and gravel mining activities. The mountainous Or Creek (23 km\(^2\)) which enters Coquitlam River about 1 km downstream of the dam is believed to be the largest contributor of sediment to the lower Coquitlam River (nhc 2001). Or Creek transports a wide range of sediment grain sizes ranging to cobbles and boulders while high eroding glaciolacustrine terrace scarps near the mouth of the creek are a significant source of silt and clay. Erosion of glaciolacustrine deposits is also observed on the west side of the river, especially during wet periods. The other main tributaries below the dam (Scott and Hoy Creek) drain less rugged watersheds roughly half the size, and are not believed to be significant sources of sediment. Sediment derived from erosion of channel banks along lower Coquitlam River has been minimal since regulation.
Gravel mining activities on the west side of the river are an additional sediment source. Wastewater from the mining is treated in settling ponds then discharged into the river. In the past, coarser sediments were delivered to the river from the mines. Occasional pond failures still result in larger- and coarser-than-normal outputs of sediment to the river. Most of the sediment currently introduced to the river consists of fine sand, silt and clay, and creates frequent turbidity events below the point of discharge. Most turbidity events observed in the river that are not related to high flows are believed to be a direct consequence of mining activities. Quilty (2003) reports that turbidity levels below the mines were up to 13 times greater than measured upstream at the (then) GVRD gate on sampled dates in 2002. The City of Coquitlam used to periodically monitor turbidity and suspended sediment concentration upstream and downstream of the gravel mines, but data collection ceased before 2006. The turbidity monitoring program was re-initiated in mid-2007, but suspended sediment samples are no longer collected. **nhc** will start collecting periodic suspended sediment in 2008 and will use the data to establish a suspended sediment rating curve once a large enough set of samples have been collected and analyzed.

### 2.2 Channel Morphology and Substrate

Lower Coquitlam River exhibits an irregularly sinuous meandering morphology with occasional bars and small islands. Changes in morphology on the lower river are mainly caused by variation in flow and sediment regimes and changes in bed slope. Land use patterns, riparian vegetation, bank strength and anthropogenic influences are secondary factors that can also affect channel form. As part of IFN (Instream Flow Needs) investigations by BC Hydro, the channel was divided into five reaches that largely reflect variations in channel morphology (Figure 1).

Reach 4 is the uppermost reach, extending from Coquitlam Dam to Or Creek confluence and has a gradient of 1.8%. The morphology of Reach 4 is dominated by large, irregularly spaced lag boulders that have fallen into the river from adjacent slopes or have been exposed by channel incision through bouldery glacial till deposits. These remnant boulders are not mobilized through normal fluvial processes. Bedload transport rates in Reach 4 would have been low even prior to regulation due to the presence of Coquitlam Lake immediately upstream.
which effectively eliminates the downstream supply of bed material. Cobbles and small boulders stored in low bars and planar bed sections represent the sediment that would have been transported during the largest floods prior to regulation. These ‘mobile’ sediments would have been mainly derived from lateral bank erosion.

Reach 3 extends downstream from Or Creek to the upstream end of the gravel mining area. Channel gradient (1.8%) is the same as measured for reach 4. Reach morphology is dominated by the coarse sediment load delivered from Or Creek. The channel bed and bars are composed mainly of cobbles and small boulders which are still transported downstream by the regulated flow regime. However, the aggradation of boulder and cobble material into forested areas at the mouth of Or Creek reflects the reduced capacity of Coquitlam River to remove all of the material supplied. Reach 3 also contains clusters of large lag boulders that would not have been mobilized even during a natural flow regime. Pockets of sand and granules occur in the lee of these lag boulders and other preferential low-velocity areas along channel margins. Given that the volume of these deposits is small relative to that supplied from Or Creek, most of this material is transported to downstream reaches. Finer, cohesive silt and clay sized sediments eroded from glaciolacustrine terrace scarps along lower Or Creek have also been observed on the coarse substrate in Reach 3 (nhc 2006). This sediment does not settle out of suspension, even at the lowest flows, but becomes attached due to inherent cohesive properties. These materials are probably removed by abrasion when sand and granules are being transported over the bed, or less frequently, when the entire bed is mobilized.

Reach 2 includes the gravel mining area and extends downstream almost to the Lougheed Highway. Average gradient declines to 1.1%. The sub-reach along the gravel mines is referred to as Reach 2B, while the downstream sub-reach through the urbanized area is referred to as Reach 2A. The morphology of Reach 2 is dominated by boulder bars and riffles which are separated by long pools and glides. In general, the bars are larger and less active (they support more vegetation) than in Reach 3 and are thought to be representative of pre-regulation bedload conditions. Smaller, unvegetated cobble bars located within the narrowed post-regulation channel are indicative of the contemporary bedload. Sand and granules are abundant in the interstices of pool and glide bed material. Isolated lag boulders occur throughout the reach, with greater accumulations of sand and granules located downstream. A
particularly large concentration of lag boulders occurs near the downstream end of the reach. Turbid conditions are often observed in Reach 2 due to effluent from the gravel mines. Cohesive fine sediment has been observed to accumulate and be removed from the bed material, as in Reach 3. The relative contribution of sand/ granule and silt/clay sediments from Or Creek versus the gravel mines is not known.

Reach 1 extends approximately 0.6 km upstream and 1.2 km downstream of Lougheed Highway and roughly corresponds to the alluvial fan as gradient declines further to 0.4% and the channel is not competent to transport bed material sediments further downstream. The channel is confined by dikes and has been aggrading for decades (*nhc* 1976, *nhc* 2001). Ongoing aggradation is evident from the accumulation of cobbles on the upstream side of young deciduous trees and plants on the bars, and finer sediment in the lee of this vegetation. The dominant substrate size class ranges from cobble at the upstream end of the reach to fine gravel at the downstream end. Gradient continues to decline (to 0.07%) in the lowermost Reach 0 which extends across the Fraser River floodplain. Reach 0 is not included in the monitoring program and is not shown in Figure 1.

### 2.3 Coquitlam River Hydrology

The Water Survey of Canada (WSC) operates a streamflow gauging station (08MH002) at the CP Rail Bridge, 0.4 km downstream of Lougheed Highway. The mean annual flood (based on daily discharge) in the lower Coquitlam River prior to regulation has been estimated at 270 m$^3$/s (*nhc* 2001). Since the onset of regulation, only three floods in 1921, 1955, and 1961 have exceeded this value. All three of these floods included uncontrolled spills at Coquitlam Dam. Since 1968, the mean annual maximum daily discharge has been 72 m$^3$/s, close to the minimum flow estimated to be required for substrate maintenance (70 to 100 m$^3$/s).

Coquitlam River flow conditions during the 2007 sampling program are presented in Figure 2. The data were provided directly by WSC and are considered preliminary and subject to change. Prior to the sampling period was a series of very large rainstorms in November 2006. Peak discharge exceeded 150 m$^3$/s during three events, and reached a maximum of 190 m$^3$/s during one event. More significantly, flows were sustained in the range of 70 to 100 m$^3$/s for at least
20 days during the month of November. Therefore, samples collected in January 2007 are expected to reflect the results of these flushing flows.

The 2006/07 hydrograph reveals a typical coastal pattern of high flows from October through March, the result of frequent frontal rain and rain on snow events. The discharge declines through the spring due to lower precipitation, but are augmented by snowmelt from high elevations of tributary watersheds. Flows are lowest in summer to early fall, though a change in the regulated flow regime in Autumn, 2008 means that in subsequent years, flows will be lowest in the June to July period and will increase in August through September. Maximum flow for the year reached 118 m$^3$/s on March 11, but the high flow was only sustained for a single day. However, during a second large storm from March 22 to 24, flows were sustained above the 70m$^3$/s threshold for three days, and remained close to the threshold for an additional two days. The May, 2007 sampling therefore, should reflect the effects of flushing flows on substrate quality assuming fine sediments accumulated between this period and the previous flushing flow in November, 2006. The flushing flow threshold was also exceeded on 3 separate days over the course of a single week in November, but maximum peak flows were smaller than in the spring, and the events do not fully meet flushing flow criteria.
3. Substrate Monitoring Methods

3.1 Overview

The surface and subsurface components of river substrate typically differ in grain-size composition and are sampled differently due to accessibility and statistical considerations (Kellerhals and Bray, 1971). The surface layer is generally coarser than the subsurface due to winnowing of fines during waning flood flows or smaller events that do not mobilize the entire bed. The reverse process can occur on regulated rivers, however, as finer sediments accumulate on the surface due to the reduction in the magnitude and duration of peak flows.

We have adopted two established techniques for characterizing the grain size distribution of the surface, which include pebble counts and photogrammetric analysis. The photogrammetric technique generally yields results that are less operator-biased than manual counts but there may be a systematic under-estimation in grain size measurements (Bunte and Abt, 2001). The subsurface layer represents the material that moves as bedload during channel forming or maintenance flows. The approach for bulk sampling and analysis of the subsurface material is well established (Church et al., 1987). A more detailed discussion of the difference between the surface and subsurface sediments, and of sampling and analysis requirements for the surface and subsurface substrate monitoring is provided in nhc (2006).

3.2 Photogrammetric Surface Samples

Photogrammetric surface samples were collected at 10 photo sample sites (PSS), as shown in Figure 1. The surface sample sites were distributed according to spawning or rearing habitat types as specified in the WUP decision process (BC Hydro 2005). To avoid duplication of effort between sites and to eliminate sampling in very coarse substrate or deep water, five of the original 15 sampling sites have been eliminated from data collection and analysis procedures. Site characteristics are presented in Appendix A and summarized in Table 2. Each photo site consists of a cross-channel transect where photos were taken at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ distance across the main channel (labelled L, M, and R for left, middle and right). Two or four photos were taken at each of the three points (L, M, R) across each transect, yielding a total of either 6 or 12 photos per site on each sample date. This sampling effort has been designed such that the truncated sample size (number of particles with a b-axis less than 64 mm) is greater than 50,
and ideally, more than 100 to make the samples statistically representative of the actual surface grain size distribution (after Kellerhals and Bray, 1971).

Surface substrate photographs were taken using a 65-cm length of 36-cm diameter Plexiglas tube, adapted from a technique used in Alaskan stream studies (Whitman et al., 2003 – see Photo 2). The tube was darkened, fitted with a clear Plexiglas bottom, and mounted with 5-cm long Plexiglass legs. A removable, darkened Plexiglass 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. A field application of the device is shown in Photo 3. Use of a digital camera with manual settings and polarizing filter allows photographs to be sampled in various light conditions and consistently produces sharp, high-resolution images. The height of the sampling tube allows for substrate to be photographed in clear water deeper than 1 m. The sampling tube can be used in moderately turbid conditions provided the water is reasonably shallow. In shallow turbid water, the clear plexiglass base can be placed close to the substrate surface, minimizing the depth of water column through which the photo is taken.

The b-axis dimension of the particle underlying each grid node is measured directly from the digital photographs on-screen using GIS software. A metal bar of known dimensions that rests on the bed in each photo is used to scale each image. A 64 mm x 64 mm ‘digital’ sampling grid is created in the GIS and superimposed on each image (see Photo 4). The 64 mm size is analogous to the division between gravels and cobbles, and was chosen as a truncation limit for the grain size analysis. Dimensions of each sampled particle are measured to the nearest tenth-millimetre and recorded into a database. The actual number of samples obtained in each photo depends on the bed material texture (i.e. the number of grid nodes occupied by grains greater than 64 mm in size), which varies considerably between sites. For photos taken on dry bar surfaces, the sampling tube is not used, yielding a much larger sampling surface from which b-axis measurements are made.

3.3 Bulk-Sieve Subsurface Samples

Bulk samples of subsurface material were collected on the gravel bars adjacent to photo sampling sites PSS #1 and #2 on May 31 2007, replicating previous bulk samples collected in
2000, 2003 and 2006. A new bulk sample was collected at PSS #7 on September 19 in an attempt to sample material that reflects typical reach conditions – i.e. within finer gravels more typical of the spawning and rearing reaches upstream. For the subsurface sampling, the surface layer of substrate was cleared away and the underlying subsurface material was excavated and weighed (Photo 5). The mass of bulk-sieve sample required to represent the subsurface depends upon the size of the largest particle in the sample (Church et al., 1987). Typically, we applied the 1% criterion, where the largest clast in the sample should not represent more than 1% of the sample mass. The subsurface bulk samples were manually excavated and sieved on-site. Fractions passing through standard-sized, square-mesh sieves were recorded and material passing through the 25-mm mesh size was collected and sent to International Plasma Labs in Richmond, B.C. for further analysis. The results of both sets of analysis were pooled together and the fraction finer-than (by mass) is plotted.

An additional effort to collect bulk samples using a freeze-core technique was attempted at sites PSS #2 and PSS #7. This technique was adopted as a potential method for collecting bulk samples in the wetted channel, which can not be sampled using the more conventional approach described above. If successful, the freeze-core technique would allow bulk samples to be collected at a greater variety of sites that are more representative of overall substrate conditions, since there are few exposed bars where 'dry' samples can be collected under most flow conditions. The sampler encloses the subsurface within an outer barrel that has been designed to retain all of the fine sediment within the gravel voids (Photo 6). However, it was found that the substrate was too coarse to inset the sampling device into the bed, except at a few isolated spots where only small samples could be obtained (Photo 7). Sampling at isolated locations (based on the ability to insert the device) introduces a bias in the overall sampling effort, hence successfully obtained samples are not likely representative of the actual subsurface grain size distribution. Given the problems with the freeze-core technique, the results of the field sampling effort are not reported, and the program has been discontinued.

We also collected manual surface samples on the gravel bars at each of the subsurface sampling sites to compare surface and subsurface composition, and to examine the trends of each over time. This procedure is commonly referred to as Wolman Sampling, and is fundamentally equivalent to the photogrammetric sampling. For the surface sampling, a tape
was laid on the bar surface and the grains underlying the tape at specified intervals were collected (Photo 8). One hundred grains were selected at each site and the b-axis of each grain was measured manually. Grains less than 10 mm were pooled together and not measured precisely due to practicality constraints.
4. Substrate Monitoring Results

4.1 Photogrammetric Surface Samples

The fraction of measured grains falling within the three indicative size ranges – greater than 10 mm and less than 64 mm, less than 10 mm and greater than 1 mm, and less than or equal to 1 mm – are presented in Appendix A and summarized in Table 3. Summary results from the 2006 sampling effort are provided for comparison. In the January 2007 sampling, only one of the 10 sites (PSS #10) had a truncated sample population falling below the preferred size of 100, but the sample size is well above the lower threshold of 50. This result reflects the additional sampling effort introduced after June, 2006 when truncated samples at 6 of 15 sites were found to fall below the desired size of 100. In the May, 2007 sampling, a single site (PSS #4) also had a truncated population below 100, but was greater than the minimum threshold of 50. Since all sampling populations are greater than the minimum threshold, they are all considered together in the subsequent discussion.

At the sites sampled in January 2007, the fraction of material less than 1 mm ranged from 1% to 12%, generally higher than in September, 2006 when this fraction was measured between 0% and 3% at all sites. Changes over this period reflect the impacts of flushing flows in November, 2006. By May, 2007, the fraction ranged from 1% to 16%, and reflects the results of a second flushing flow in March, 2007 (Table 3). The change in the distribution of the fine fraction over time for the different sampling sites is given in Table 4 and results are plotted in Figure 3. Figure 4 summarizes changes in the fraction of sample points within a size class between consecutive dates. Positive values indicate an increase in a particular grain-size class, while negative values indicate a decrease in a particular grain-size class over that period. There does not appear to be any clear pattern indicating that the flushing flows have systematically altered the surface composition of sands, although there is more sand in general at all sample sites after the November flushing flows. The possibility that this difference partly reflects operator bias (the results were computed by separate individuals) must be considered. Confounding any clear understanding of processes that result in the observed changes is the fact that flows much smaller than threshold are able to transport particles < 1 mm. In contrast,
from January to May, the increase in the percentage of sands was generally less, with several reaches showing a modest decrease.

The size fraction in the 1 to 10 mm size class ranged from 5% to 28% in January, 2007, generally less than in Sept, 2006 when this fraction ranged from 9% to 46% (Table 3). However, the highest fractional value in the September survey was at a site not monitored in 2007. While not conclusive, these results suggest that the November flushing flows were effective at improving over-winter substrate quality in most reaches. By May, 2007, the fraction of material in the 1 to 10 mm size class ranged from 10% to 20%, with ‘middle reaches’ showing little change or modest additional declines (Figure 5 and Figure 6). This may indicate that the supply of finer sediments that were removed by the November flushing flows was sufficiently reduced such that the effects of a second flushing flow a few months later was comparatively modest. The fractional increase in PSS #15 may be due to small variations in sampling location, or could reflect new inputs below the dam. The fractional increase at sites PSS #1 and #2 is consistent with the ‘winnowing’ of this material in upstream reaches, and deposition in reach 1 where gradient declines and this material would be expected to deposit.

The fraction of material in the 1 to 10 mm size class generally increases in a downstream direction from Reach 4 to Reach 2A, then declines to Reach 1 for both September 2006 and January 2007 sampling periods. The downstream increase in fine sediment content on the riverbed corresponds to the available supply of this material upstream (from Or Creek and gravel mines) and reduced channel gradient and stream power downstream. However, this trend is not strong, and does not hold in the May 2007 period when the fractional proportion of this material was nearly constant to increasing slightly in a downstream direction.

The seemingly paradoxical decrease in fine sediment content that has been documented in Reach 1 may reflect the higher degree of substrate sorting in that lower reach. It has been argued (nhc, 2006) that the well-sorted gravels in Reach 1 offer fewer protected sites for fine-sediment accumulation than do the coarser materials found upstream, such as the large lag boulders found in Reach 2A. The 64-mm truncation limit also affects the results to a much greater extent in bouldery reaches than in Reach 1 where much of the bed material is less than 64 mm. For example, only 2-4% of the sampled points at PSS #1 between September 2006
and May 2007 were greater than 64 mm, significantly less than the same fraction in upstream reaches for all sampling dates (Table 3). Thus, a direct comparison of truncated results between sites is less useful than a comparison of results for a given site over time. The increase in finer sediment observed in the 2007 samples counters this trend, and appears to follow the expected result of flushing flows where this material should be removed from upstream reaches and transported downstream to the lower reach. Future monitoring should reveal whether this trend is maintained (following annual flushing flows) or the fine fraction is winnowed away by more modest floods.

4.2 Pebble Counts

The manual surface samples collected on the gravel bars in May 2007 contained fine-sediment fractions (less than 10 mm diameter) of 12% and 15% at PSS #1 and #2 respectively (Table 5, Figure 7). The breakdown between the fraction finer and coarser than 1 mm was not measured. The PSS #1 result is not significantly different from previous sample results when the fine-sediment fraction ranged from 10% to 11% between 2000 and 2006. The PSS #2 result shows a large increase from the 5% measured in 2006, but is reasonably similar to prior results in 2000 and 2003 when the fine-sediment fraction ranged from 17% to 19%. It is not clear that these differences represent true changes in substrate composition over time, or if the 2006 result is an aberration based on differences in sampling location. However, a comparison of median grain sizes (the grain size for which 50% the stones are smaller or larger) at each site reveals a similar trend. The median grain size at PSS #1 was 29 mm in 2006 which falls between the 2000 value of 28 mm and the 2003 value of 35 mm. In the 2007 sampling, the median grain size 27 mm, nearly identical to the values reported in 2000 and 2006.

The median grain size at PSS #2, in contrast, consistently coarsened from 36 mm in 2000, to 42 mm in 2003, and to 50 mm in 2006, but has since become finer (41 mm in 2007). The observed bar coarsening at PSS #2 to 2006 is in agreement with anecdotal observations of gravel build-up behind vegetation on the bar and surveyed increases in the channel bed elevation in that section of Reach 1 (nhc 2001). This aggradation is a consequence of channel confinement on the alluvial fan, specific to Reach 1, and should not be confused with any reductions in fine-sediment content on the channel bed further upstream that may be achieved through flushing flows. The decrease in median surface grain size in reach 1 (PSS #1, 2) may
indicate that flushing flows in November 2006 and March 2007 have introduced finer gravels which have deposited on the existing bar surfaces. The sampling sites may again coarsen over time as finer gravels are winnowed from the surface during smaller than threshold flows.

Comparison of the photogrammetric and manual pebble-count methods of substrate surface sampling in the channel environment at PSS #1 and #2 indicates that the two techniques provide similar grain size distributions overall, so the techniques appear to be comparable (Figures 8 and 9). Some difference in the distributions is to be expected because the sampling locations differ, and the bar surface is not homogenous. The photogrammetric technique reveals a D50 of approximately 25 mm at PSS #1, somewhat finer than the 27 mm using the pebble count technique. Overall, the photogrammetric technique shows a finer distribution of material smaller than the median grain size, including a slightly higher estimate of material less than 10 mm (14%, vs. 12% for the pebble counts). At PSS #2, the photogrammetric technique reveals a D50 of approximately 42 mm, slightly larger than the pebble count (40 mm) but a coarser distribution of material finer than the median grain size (10% less than 10 mm vs. 16% for the pebble count). For comparison, the D50 was estimated to be roughly 45% using both methods in 2006. These differences probably reflect some actual differences in bed material distributions, but also biases in the two techniques. Most commonly, pebble counts underestimate the frequency of finer material.

4.3 Bulk-Sieve Subsurface Samples

The 2007 subsurface sampling results indicate that the fraction of fine sediment (less than 10 mm diameter) at the Reach 1 gravel bar sites was 42% at PSS #1 and 45% at PSS #2. At PSS #1, the breakdown was 14% less than 1 mm, and 28% between 1 to 10 mm. At PSS #2, the breakdown was 16% less than 1 mm, and 29% between 1 to 10 mm. The 2007 results show that the fraction of finer sediments is slightly reduced from earlier sampling periods (2000, 2003, and 2006) where the 1 to 10 mm fraction ranged from 47 to 50% at site 1 and is slightly greater than the 40 to 42% range at previously reported at site 2 (Figure 10). There is a large apparent decrease in the amount of fine sands (< 1 mm), at PSS #1, however, as 2006 sampling shows 24% in this size class, although the results at PSS #2 are identical. This change may be related to aggradation of gravels in this section of riversuch that the percentage of sands is becoming proportionately less. Additional bulk sampling will be required to interpret
these results more fully. Prior to 2006, the total fraction less than 10 mm was the key grain-size class of interest, so the breakdown between finer and coarser than 1 mm was not accurately recorded.

The fraction of fine sediment less than 10 mm at Site PSS #7 is 44%, with 13% less than 1 mm and 31% between 1 and 10 mm. No bulk samples have previously been collected at this location, so this result represents a baseline value for future comparisons.

The D$_{50}$ of the subsurface samples is nearly identical at all sites (Figure 10) and the finer distributions are also very similar. The distributions start to diverge above the 32 mm clast size, with Sites PSS #1 and #2 showing coarser distributions than at PSS #7 upstream (this same pattern was found in the 2006 sampling). The largest stones are found at PSS #2. The D$_{90}$ (which approximates the size of the largest stones mobilized by most large flows) has not changed significantly since 2006.
5. Turbidity Monitoring

5.1 Background

Turbidity data has been periodically collected by the City of Coquitlam between October, 2004 and August 2005 and since May, 2007 at locations near Galette Avenue (the lower site) and upstream of Falacea Creek confluence (the upper site). These locations bracket upper and lower bounds of active gravel mining activities adjacent to Coquitlam River. The intended purpose of this data collection effort is to examine the incremental effects of gravel mining operations on water turbidity and the relation to flushing flow effectiveness. Turbidity is an optical property of the flow that causes light to be scattered and absorbed (making the water appear cloudy) rather than being transmitted in a straight line (where the water remains clear). Turbidity is related to the amount of suspended solids in the water (mainly silts and clays), but can include any suspended material including pollutants and organics.

Since turbidity is related to the amount of suspended solids in the water, it can be related to sediment yield if the total amount of suspended solids (TSS) is also known. TSS measurements are normally taken as samples at different flows (because of the time and effort involved in collecting and analyzing the data) and are related to turbidity using a rating curve (best-fit line of the data). TSS samples need to taken over a range of flows because turbidity tend to increase, in general, with discharge since higher flows are associated with greater precipitation and sediment runoff. The relation may also be non-linear. It is also important to collect a sufficiently large number of samples to establish a reliable rating curve because the relation between TSS and discharge can be highly scattered. The rating curve is subsequently used to estimate TSS for periods when there was no sampling, as turbidity is generally measured at continuous intervals. The product of TSS and mean discharge gives the total suspended sediment load over the period of measurement.

There are a number of problems with the available data, including significant gaps within the records for each station, and regarding overlap between stations. More importantly, there have no attempts to collect total suspended solids measurements since 2004/05, so the effects of the gravel mining operations in relation to the effectiveness of the flushing flows can not be
investigated. Despite this limitation, the available data clearly indicate that gravel mining activities increase turbidity levels. Additional sampling efforts planned for the current year (and extending to 2010) will be used to define the relation between TSS and turbidity, hence to estimate annual sediment loads and investigate the relation between sediment discharge from gravel mining operations and flushing flow effectiveness.

5.2 Available Data

The turbidity data collection efforts by the City of Coquitlam between October, 2004 and August, 2005 included concurrent measurements of rainfall intensity, dissolved oxygen, water pH, water temperature, total dissolved solids, flows at Coquitlam River gage and dam discharge. Most of these measures are of water quality and are not central to the sediment / flushing flow discussion. There are numerous gaps in the data records, no written documentation of the data collection procedures and no discussion of results. In addition, the data have been provided in graphic form only – there are no digital records. A summary of the relevant data are given in Table 6 below.

Flow records are generally complete (so they overlap the turbidity records) but there are a number of daily and part-daily gaps. The plotted data likely used preliminary WSC records (which are subject to change) and some gaps may have been subsequently fixed. It might also be possible to interpolate missing flows using release data from Coquitlam Dam.

A relation between TSS and turbidity is provided in the report based on 5 samples at each of the two monitoring sites (Figure 11). It is assumed that the data were collected on the same dates (hence represent actual variability in turbidity due to gravel mining operations, not differences in rainfall or discharge) but this is not known with certainty. Based on the analysis of suspended sediment samples, the amount of total suspended solids (mg/L) at any sampling time is equal to half the NTU reading. For the highest turbidity readings in the table (roughly 2000 NTUs) this is equivalent 1000 mg, or 1 gram per litre when discharge at the Coquitlam gauge exceeded 150 m$^3$/s in January, 2005. Additional sampling is required to establish whether this relation is still valid. In general these data clearly demonstrate that turbidity and TSS are consistently higher at the downstream monitoring station indicating that gravel mining operations are a source of fine sediment that is introduced to Coquitlam River. However, these
data are not sufficient to claim that this sediment degrades the subsurface habitat quality, and that flushing flow releases are effective at removing this material because the size distribution of material discharged from the mining operations has not been related to material found in the subsurface.

The program was terminated in mid-August, 2005 and resumed in May, 2007. The more recent records also contain many gaps, both within and between months, including periods when upper and lower sensors were not working at the same time. This makes it difficult to examine the impacts of the gravel mines on downstream sediment inputs. There are no data at all for 2006, when the substrate monitoring program was re-commenced. In addition, suspended sediment samples have not been collected since turbidity data collection was restarted in 2007. The relation $TSS = \frac{1}{2} NTU$ should not be used to estimate TSS concentration for 2007 until additional samples have been collected and analyzed so that the relation can be verified or revised. Table 7 summarizes the more recent data collection efforts.

Discharge records are generally complete, but the records are preliminary and subject to change. Data for 2008 have not yet been compiled for release by WSC. Part of the flow record for July is clearly in error as discharge remains constant at 3.6 m$^3$/s from July 10 to July 20 (to 14:00 hrs) and increases to 22 m$^3$/s in the following 15-minute measuring period. In general, there is relatively little data collected simultaneously at upper and lower sites which was due mainly to sensor malfunction (Melanie Burton, City of Coquitlam, pers comm). The July turbidity data appear suspicious at the upper site as turbidity readings remain nearly constant in (0.68 NTU) for the 4 days while turbidity values at the lower site fluctuate above and below this value (Figure 12). Turbidity remains very low at the upper site in the October-November period, though discharge is also very low (Figure 13).

The data illustrate, in general, that turbidity is lowest at the sampling station upstream of the gravel mining and increases significantly downstream. If this effect is real (i.e. not an artefact of sampler error) then the relation between discharge and turbidity at the downstream station should be highly scattered relative to that at the upstream station (Figure 14). This plot shows a clear positive trend between turbidity and discharge at the upper site with little scatter (some scatter is expected, mainly because of sporadic inputs from Orr Creek). If the upstream data
are reliable, then the significant scatter below the gravel mining operations must be due to sediment inputs from this activity. The downstream readings are also up to 3 orders of magnitude greater than at the upstream site, but downstream readings are similar in magnitude to those previously reported in October and November, 2004. No TSS samples were collected along with this more recent turbidity data, and the data can not be directly related to changes in subsurface habitat quality.

5.3 Future Work

The available rating curve (turbidity vs. TSS) from the City of Coquitlam requires verification and further refinement before available (and on-going) turbidity data can be related to total suspended sediment. Additional sampling efforts are planned for the current year (and extending to 2010) and will be used to better define the relation between TSS and turbidity, hence to estimate annual sediment loads. An additional effort to determine the size distribution of this sediment is also planned for the current year. The size distribution is required to relate sediment discharge from gravel mining operations to flushing flow effectiveness.
6. Conclusions

Reaches 2 and 3 provide the most important salmonid habitat in the lower Coquitlam River (BC Hydro Instream Flow Needs (IFN) investigations). The channel is characterized by coarse substrate with accumulations of sand and finer particles on the surface between the coarser stones. The presence of fine material indicates that subsurface voids are essentially filled with fine sediment, although this condition may be limited to a certain depth. There is currently no program in place to assess subsurface substrate conditions within the wetted channel. Accumulations of finer, cohesive sediment (silts and clays) have also been observed adhering to the coarser stones on the substrate surface, but this condition has not been directly monitored.

The largest tributary, Or Creek, is thought to be the largest contributor of sand and granule material to the lower Coquitlam River (nhc 2001). Therefore, the same high tributary flows that deliver sediment to the river are expected to flush the sediment down the river and out of the critical habitat reaches. Thus, the dynamics of sediment delivery to the river during these events and the variability in the duration of high flows makes the prediction of substrate conditions difficult. In general, it is expected that the tributary sediment inputs are greatest during the early stages of flood events and that prolonged high-flow events will result in a net flushing of the river substrate.

Photogrammetric surface samples were collected in January and May 2007 to document the fraction of surface material falling within the less than 1 mm, and 1 to 10 mm size classes. Following the September 2006 sample collection, a series of high-flow events occurred in November 2006 in which the flushing threshold was reached or exceeded for around 20 days. Flushing flow criteria were again reached in March 2007, when flows were near or greater than the threshold for five days. Therefore, the samples that have been collected in January 2007 and May provide an opportunity to evaluate flushing flow effectiveness for the first time.

Photogrammetric surface samples collected in 2006 indicate that the fraction of material less than 1 mm is generally much lower than the fraction in the 1 to 10 mm class. In January 2007, the fraction less than 1 mm ranged from 1% to 12%; in May 2007, the fraction less than 1 mm
ranged from 1% to 16%. The fraction in the 1 to 10 mm size class ranged from 5% to 28% in January, and from 12% to 20% in May. The greatest fractions of fine sediment (total less than 10 mm) occur in Reach 2A, due to a combination of physical factors and sampling constraints. Reach 2A lies downstream of Or Creek and the gravel mines which contribute fine sediment to the river and the reach has a lower gradient (hence stream power) than Reach 3. Reach 2A also contains a high concentration of large lag boulders that create sheltered areas for fine sediment accumulation. These boulders also complicate the sampling process by constraining the location of sample collection so that sample results are not representative of the overall substrate, but rather represent unique micro-sites between boulders. An unusually high fraction of fine sediment was also observed at PSS #15 in the May sampling. It is not known if this increase is related to construction near the dam, is the result of another [unknown] sediment source upstream, or is the result of sampling variability.

From September 2006 to January 2007, there was a general decline in the fraction of material less than 10 mm and a further, smaller reduction by May which suggests the flushing flows have been effective in reducing the accumulation of fine sediments, hence in improving substrate quality for fish habitat. The generally smaller changes in the January - May period are apt to be related to sediment supply limitations, whereby a sufficient amount of this material was removed during the November flushing flows that the March flows were comparatively less effective. The fractional increase in finer sediment in reach 1 is consistent with a winnowing of this material from upstream reaches, and deposition downstream where the gradient is reduced. Despite the apparently positive effects of the flushing flows, there was an apparent observed increase in the amount of material finer than 1 mm, with more material found in January than the previous September, despite the flushing flows. However, this fraction was reduced by May. It is not known if these changes represent operator bias, or are representative of actual conditions on those dates.

Bulk samples collected at two gravel bar sites in Reach 1 were found to have 42% and 45% fractions less than 10 mm. These values are somewhat smaller than was recorded in 2000, 2003 and 2006 at the same sites. Manual surface samples collected at these two sites indicate that the lowermost site (PSS #1) has approximately 12% less than 10 mm, and that this fraction has remained essentially constant since 2000. At the upstream site (PSS #2), however, the
surface material had initially coarsened since 2000, with the fraction less than 10 mm decreasing from 19% in 2000 to 5% in 2006, but had become finer by 2007. This coarsening was believed to be related to aggradation on the alluvial fan of Coquitlam River, and the consequent progradation of coarser material in a downstream direction in the confined fan channel. Consequently, a comparison of surface and subsurface results in Reach 1 is not generally applicable to Reaches 2 and 3. It is likely that more recent fining in reach 1 is related to the erosion of this material upstream during the flushing flows, and subsequent deposition downstream. Winnowing of this finer material during flows less than the flushing flow are apt to coarsen the material in the fan over time.
7. References


TABLES
<table>
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<tr>
<th>Date</th>
<th>Incubation mid-point</th>
<th>Fry emergence</th>
<th>Photo sampling</th>
<th>Conditions</th>
<th>Sampling Method</th>
<th>PSS</th>
<th>PSS</th>
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<td>12-Sep-07</td>
<td>Unfavourable conditions</td>
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<td>26-Oct-07</td>
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<td>1-May-07</td>
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<td>Bulk sampling</td>
<td>PSS 7</td>
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**TABLE 1: Summary Target Dates**
TABLE 2: Coquitlam River Photogrammetric Surface Sampling Sites

<table>
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<tr>
<th>NEW SITES</th>
<th>REACH</th>
<th>HABITAT</th>
<th>PREVIOUS SITE NAMES</th>
<th>LOCATION</th>
<th>PHOTO POINT - DISTANCE (m) FROM LEFT BANK PN</th>
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<tr>
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<td>DOMINANT MATERIAL</td>
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### TABLE 3: Photogrammetric Surface Sampling Results

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<tr>
<th>REACH (PS5)</th>
<th>JUN 2006</th>
<th>FRACTION OF SAMPLED GRAINS WITH DIAMETER “D” IN SIZE RANGE (mm)</th>
<th>SEP 2006</th>
<th>JAN 2007</th>
<th>MAY 2007</th>
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<td>TRUNCATED SAMPLE (D ≤ 64 mm)</td>
<td>TOTAL SAMPLE</td>
<td>TRUNCATED SAMPLE (D ≤ 64 mm)</td>
<td>TOTAL SAMPLE</td>
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<td>n</td>
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<td>13</td>
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<td>15%</td>
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<td>15%</td>
<td>85%</td>
<td>81</td>
</tr>
<tr>
<td>2B</td>
<td>8</td>
<td>8%</td>
<td>28%</td>
<td>64%</td>
<td>25</td>
</tr>
<tr>
<td>2B</td>
<td>7</td>
<td>6%</td>
<td>33%</td>
<td>61%</td>
<td>94</td>
</tr>
<tr>
<td>2A</td>
<td>4</td>
<td>4%</td>
<td>28%</td>
<td>68%</td>
<td>51</td>
</tr>
<tr>
<td>2A</td>
<td>3</td>
<td>3%</td>
<td>28%</td>
<td>68%</td>
<td>88</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0%</td>
<td>16%</td>
<td>84%</td>
<td>166</td>
</tr>
</tbody>
</table>

**NOTES:**

1) SAMPLE RESULTS SHADED LIGHT GREY HAVE POPULATION SIZE BELOW THE PREFERRED MINIMUM NUMBER OF B-AXIS MEASUREMENTS (100); COMPARISON OF RESULTS MAY NOT BE ACCURATE.

2) SAMPLE RESULTS SHADED DARK GREY HAVE POPULATION SIZE BELOW THE ACCEPTABLE MINIMUM NUMBER OF B-AXIS MEASUREMENTS (50); COMPARISON OF RESULTS SHOULD NOT BE MADE.
### TABLE 4: Photogrammetric Surface Sampling Comparison over Time

<table>
<thead>
<tr>
<th>REACH</th>
<th>SITE (PSS)</th>
<th>CHANGE IN FRACTION OF SAMPLED GRAINS WITH DIAMETER &quot;D&quot; IN SIZE RANGE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D ≤ 1</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>1%</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>3%</td>
</tr>
<tr>
<td>2B</td>
<td>10</td>
<td>12%</td>
</tr>
<tr>
<td>2B</td>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>2B</td>
<td>8</td>
<td>7%</td>
</tr>
<tr>
<td>2B</td>
<td>7</td>
<td>4%</td>
</tr>
<tr>
<td>2A</td>
<td>4</td>
<td>0%</td>
</tr>
<tr>
<td>2A</td>
<td>3</td>
<td>8%</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>6%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>

**NOTES:**

1) COMPARISON OF JUNE 2006 AND SEP 2006 SAMPLE RESULTS, TRUNCATED AT 64 MM.
2) POSITIVE VALUES INDICATE INCREASE IN FRACTION OF SAMPLED GRAINS WITH DIAMETER "D" WITHIN SIZE RANGE FROM JUNE TO SEP 2006 AND JANUARY TO MAY 2007.
3) SAMPLE RESULTS SHADED LIGHT GREY HAVE POPULATION SIZE BELOW THE PREFERRED MINIMUM NUMBER OF B-AXIS MEASUREMENTS (100) IN JUNE 2006, JANUARY AND MAY 2007; COMPARISON OF RESULTS MAY NOT BE ACCURATE.
4) SAMPLE RESULTS SHADED DARK GREY HAVE POPULATION SIZE BELOW THE ACCEPTABLE MINIMUM NUMBER OF B-AXIS MEASUREMENTS (50) IN JUNE 2006, JANUARY AND MAY 2007; COMPARISON OF RESULTS SHOULD NOT BE MADE.
# TABLE 5: Summary of manual surface samples

<table>
<thead>
<tr>
<th>SITE (PSS)</th>
<th>FRACTION OF SAMPLED GRAINS WITH DIAMETER &quot;D&quot; IN SIZE RANGE (mm)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D ≤10</td>
<td></td>
<td></td>
<td></td>
<td>D &gt; 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11%</td>
<td>10%</td>
<td>10%</td>
<td>12%</td>
<td>89%</td>
<td>90%</td>
<td>90%</td>
<td>88%</td>
</tr>
<tr>
<td>2</td>
<td>19%</td>
<td>17%</td>
<td>5%</td>
<td>15%</td>
<td>81%</td>
<td>83%</td>
<td>95%</td>
<td>85%</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>86%</td>
</tr>
</tbody>
</table>
TABLE 6: Summary of available turbidity data, 2004-2005

<table>
<thead>
<tr>
<th>Period</th>
<th>Coquitlam turbidity- available dates</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper site</td>
<td>Lower site</td>
</tr>
<tr>
<td>Oct 2004</td>
<td>1-12, 28-31</td>
<td>1-12, 28-31</td>
<td></td>
</tr>
<tr>
<td>Nov 2004</td>
<td>1-4, 16-20</td>
<td>1-12, 28-31</td>
<td>1-30</td>
</tr>
<tr>
<td>Dec 2004</td>
<td>17-31</td>
<td>17-31</td>
<td>1-8, 16-31</td>
</tr>
<tr>
<td>Jan 2005</td>
<td>1-20, 27-31</td>
<td>1-20, 27-31</td>
<td>1-28</td>
</tr>
<tr>
<td>Feb 2005</td>
<td>1-20</td>
<td>1-20</td>
<td>1-28</td>
</tr>
<tr>
<td>June 2005</td>
<td>17-30</td>
<td>17-30</td>
<td>4-30</td>
</tr>
<tr>
<td>July 2005</td>
<td>1-12, 16-31</td>
<td>1-12, 16-31</td>
<td></td>
</tr>
<tr>
<td>Aug 2005</td>
<td>1-15</td>
<td>1-15</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 7: Summary of available turbidity data, 2007-2008

<table>
<thead>
<tr>
<th>Period</th>
<th>Coquitlam turbidity- available dates</th>
<th>Upper site</th>
<th>Lower site</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2007</td>
<td>23-31</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>June 2007</td>
<td>1-20</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>July 2007</td>
<td>10-14</td>
<td>10-22</td>
<td></td>
</tr>
<tr>
<td>Oct 2007</td>
<td>23-31</td>
<td>23-31</td>
<td></td>
</tr>
<tr>
<td>Nov 2007</td>
<td>1-8</td>
<td>1-8</td>
<td></td>
</tr>
<tr>
<td>Jan 2008</td>
<td>2-31</td>
<td>2-31</td>
<td></td>
</tr>
</tbody>
</table>
NOTES:

*PSS #1 - ADDITIONAL PEBBLE-COUNT SAMPLE (CHANNEL)
*PSS #2 - ADDITIONAL PEBBLE-COUNT AND PHOTOGRAMMETRIC SAMPLES (BAR)
*PSS #1 AND #2 - ADDITIONAL BULK-SIEVE SAMPLES (BAR)
FIGURE 2: Annual daily discharge 2007 with target dates

- Incubation mid-point
- Fry emergence
- Photo sampling
- Freeze core sampling
- Bulk sampling
- Start of spawning
- Surface, bulk, photo sampling
- Freezing core sampling
- Bulk sampling
- Start of spawning
- Photo sampling
FIGURE 3: Photogrammetric Surface Sampling Results D≤1
Coquitlam River, PSS 1-15 (Sep 2006 - May 2007)
FIGURE 4: Photogrammetric Surface Sampling Results D≤1 Difference

PHOTOGRAMMETRIC SAMPLING SITE

FRACTION IN SIZE RANGE (%)
FIGURE 5: Photogrammetric Surface Sampling Results 1<D≤10
Coquitlam River, PSS 1-15 (Sep 2006 - May 2007)

PHOTOGRAMMETRIC SAMPLING SITE

FRACTION IN SIZE RANGE (%)

R - 4   R - 3   R - 2B   R - 2A   R - 1

15 13 10 9 8 7 4 3 2 1

1<D≤10 Sept06 1<D≤10 Jan07 1<D≤10 May07
FIGURE 6: Photogrammetric Surface Sampling Results $1 < D \leq 10$ Difference
FIGURE 7: Pebble-Count Surface Samples

Coquitlam River - May/Sept, 2007

The graph illustrates the grain size distribution for different samples labeled PSS #1, PSS #2, and PSS #7. The x-axis represents the grain size B-axis (mm), while the y-axis shows the fraction finer (%). The samples show varying degrees of fine-grained material, with PSS #1 having a higher fraction finer at smaller grain sizes compared to PSS #2 and PSS #7.
FIGURE 8: Comparison of Photogrammetric and Pebble-Count Surface Samples

Coquitlam River, PSS #1 (Bar) - 2007
FIGURE 9: Comparison of Photogrammetric and Pebble-Count Surface Samples
Coquitlam River, PSS #2 (Bar) - 2007

![Graph comparing Photogrammetric and Pebble-Count surface samples for Coquitlam River, PSS #2 (Bar) in 2007. The graph shows the fraction finer (%), with 100% representing the fraction of grains finer than a certain size, against grain size (mm). The graph includes two lines: one for Photogrammetric and the other for Pebble-Count.]
FIGURE 10: Bulk Sieve Subsurface Samples Coquitlam River - 30 MAY 2007

GRAIN SIZE (mm) vs. FRACTION FINER (%) for PSS 1, PSS 2, and PSS 7.
FIGURE 11: Relation between total suspended solids and turbidity
FIGURE 12: Upper and lower Coquitlam turbidity, July 2007
FIGURE 13: Upper and Lower Coquitlam turbidity, October-November 2007

Upper and Lower Coquitlam River NTU
Oct 23 - Nov 8, 2007

Turbidity (NTU)

Discharge (m$^3$/s)

Date

0 10
20
30
40
50
60
70

0
10
20
30
40
50
60
70

10/21/07 10/23/07 10/25/07 10/27/07 10/29/07 10/31/07 11/02/07 11/04/07 11/06/07 11/08/07 11/10/07

Upper
Lower
Discharge
FIGURE 14: Relation between turbidity and discharge, October-November 2007
PHOTOGRAPHS
PHOTO 1
Clear conditions near PSS 15 during low-flow winter period.
(1 Feb 07)

PHOTO 2
Photogrammetric sampling apparatus. The Plexiglas tube has a mounting device and viewing hole for the camera. The bottom is clear. The clear Plexiglas feet allow light to enter the bottom.
PHOTO 3
Photogrammetric sampling apparatus being used at PSS 15. (1 Feb 07)

PHOTO 4
Sample digital photograph with sampling grid.
PHOTO 5
Gravel bar substrate subsurface sampling using the traditional bulk-sieve technique. (30 May 07)

PHOTO 6 Freeze-core sampling in wetted channel near PSS 2 (12 Sept 07)
PHOTO 7
Freeze-core sample. (12 Sept 07)

PHOTO 8
Surface pebble counts near PSS 1. (30 May 07)
APPENDIX A
### PSS 15

**LOOKING UPSTREAM OF PSS 15 (27 SEP 2006)**

**LOOKING DOWNSTREAM OF PSS 15 (27 SEP 2006)**

**PSS 15 – L1 (31 JAN 2007)**

**PSS 15 – R2 (30 MAY 2007)**

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>D ≤ 1</td>
<td>1 ≤ D &lt; 10</td>
</tr>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n₁ = 145</td>
<td>n = 220</td>
</tr>
<tr>
<td>1%</td>
<td>5%</td>
<td>94%</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>30 MAY 2007</td>
<td>6.0</td>
<td>CLEAR</td>
<td>n₁ = 146</td>
<td>n = 236</td>
</tr>
<tr>
<td>1%</td>
<td>14%</td>
<td>86%</td>
<td>38%</td>
<td></td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n₁ = TRUNCATED SAMPLE SIZE (D < 64 mm)
### PSS 13

**LOOKING UPSTREAM OF PSS 13 (31 JAN 2007)**  

**LOOKING DOWNSTREAM OF PSS 13 (27 SEPT 2006)**

**PSS 13 – M4 (31 JAN 2007)**  

**PSS 13 – R4 (16 MAY 2007)**

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>D ≤ 1</td>
<td>1 ≤ D &lt; 10</td>
</tr>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 123</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3%</td>
<td>20%</td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>n_T = 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>13%</td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)

---

*BC Hydro – Lower Coquitlam River Substrate Quality Assessment  
2006 Annual Data Report (FINAL), May 2007*
### PSS 10

**LOOKING UPSTREAM OF PSS 10**
(27 SEP 2006)

**LOOKING DOWNSTREAM OF PSS 10**
(27 SEP 2006)

**PSS 10 – L1 (31 JAN 2007)**

**PSS 10 – L3 (16 MAY 2007)**

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 96</td>
<td>n = 204</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11%</td>
<td>53%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>66%</td>
<td></td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>n_T = 121</td>
<td>n = 261</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3%</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85%</td>
<td></td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)

---

*BC Hydro – Lower Coquitlam River Substrate Quality Assessment*

*2006 Annual Data Report (FINAL), May 2007*
PSS 9

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 112</td>
<td>n = 241</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4%</td>
<td>18%</td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>n_T = 119</td>
<td>n = 284</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7%</td>
<td>16%</td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)
PSS 8

LOOKING UPSTREAM OF PSS 8 (28 SEP 2006)

LOOKING DOWNSTREAM OF PSS 8 (28 SEP 2006)

PSS 8 – L1 (31 JAN 2007)

PSS 8 – M3 (16 MAY 2007)

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 111</td>
<td>n = 201</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>n_T = 157</td>
<td>n = 266</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3%</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)
PSS 7

LOOKING TOWARD LEFT BANK
(28 SEP 2006)

LOOKING DOWNSTREAM OF PSS 7
(28 SEP 2006)

PSS 7 – L2 (31 JAN 2007)

PSS 7 – R1 (16 MAY 2007)

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 149</td>
<td>n = 215</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7% 19% 74% 31%</td>
<td></td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>n_T = 145</td>
<td>n = 251</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5% 10% 85% 42%</td>
<td></td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)
PSS 4

LOOKING TOWARD LEFT BANK (28 SEP 2006)

LOOKING DOWNSTREAM OF PSS 4 (28 SEP 2006)

PSS 4 – R4 (31 JAN 2007)

PSS 4 – M3 (16 MAY 2007)

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>D ≤ 1  1 ≤ D &lt; 10  10 ≤ D &lt; 64</td>
<td>n_T = 101  n = 275</td>
</tr>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>2%  28%  70%</td>
<td>63%</td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>6%  12%  82%</td>
<td>74%</td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)
## PSS 3

### LOOKING TOWARD LEFT BANK (28 SEP 2006)

### LOOKING DOWNSTREAM OF PSS 3 (28 SEP 2006)

### PSS 3 – M1 (31 JAN 2007)

### PSS 3 – L4 (16 MAY 2007)

### Table: Water Clarity and Flow at PSS 3

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>D ≤ 1</td>
<td>1 ≤ D &lt; 10</td>
</tr>
<tr>
<td>31 JAN</td>
<td>3.7</td>
<td>CLEAR</td>
<td>nₜ = 117</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>16 MAY</td>
<td>6.1</td>
<td>CLEAR</td>
<td>nₜ = 176</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td>13%</td>
<td>18%</td>
</tr>
</tbody>
</table>

where \( n \) = TOTAL SAMPLE SIZE; \( nₜ \) = TRUNCATED SAMPLE SIZE (D < 64 mm)

---

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### PSS 2

**LOOKING UPSTREAM OF PSS 2**
(30 MAY 2007)

**LOOKING DOWNSTREAM OF PSS 2**
(30 MAY 2007)

**PSS 2 – M2**
(31 JAN 2007)

**PSS 2 – R3**
(16 MAY 2007)

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>nₜ = 179</td>
<td>n = 186</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1% 14% 85% 4%</td>
<td></td>
</tr>
<tr>
<td>16 MAY 2007</td>
<td>6.1</td>
<td>CLEAR</td>
<td>nₜ = 245</td>
<td>n = 249</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16% 20% 64% 2%</td>
<td></td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; nₜ = TRUNCATED SAMPLE SIZE (D < 64 mm)
## PSS 1

### LOOKING UPSTREAM OF PSS 1 (30 MAY 2007)

### LOOKING DOWNSTREAM OF PSS 1 (30 MAY 2007)

### PSS 1 – M3 (31 JAN 2007)

### PSS 1 – L3 (30 MAY 2007)

<table>
<thead>
<tr>
<th>DATE</th>
<th>FLOW (m³/s)</th>
<th>WATER CLARITY</th>
<th>TRUNCATED D &lt; 64 mm</th>
<th>D &gt; 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 JAN 2007</td>
<td>3.7</td>
<td>CLEAR</td>
<td>n_T = 179</td>
<td>n = 186</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td>14%</td>
</tr>
<tr>
<td>30 MAY 2007</td>
<td>6.0</td>
<td>CLEAR</td>
<td>n_T = 245</td>
<td>n = 249</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16%</td>
<td>20%</td>
</tr>
</tbody>
</table>

where n = TOTAL SAMPLE SIZE; n_T = TRUNCATED SAMPLE SIZE (D < 64 mm)

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*BC Hydro – Lower Coquitlam River Substrate Quality Assessment*

*2006 Annual Data Report (FINAL), May 2007*