2014 Sediment Transport Investigation on the Vanderhoof Reach of the Nechako River

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CERTIFICATION

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EXECUTIVE SUMMARY

The development of Kenney Dam and the Skins Lake Spillway as part of the Kemano Project in the early 1950's caused changes in flow and sediment supply to the Nechako River. In conjunction with these changes there has been a reduction in juvenile White Sturgeon production, with the low number of juvenile sturgeon being attributed to changes in spawning habitat. The Vanderhoof Reach has been identified as a critically important spawning reach, prompting several investigations to assess the historical and contemporary characteristics of the reach.

As part of the ongoing sturgeon recovery effort for the Nechako River, Northwest Hydraulic Consultants Ltd. (NHC) developed a suspended sediment and bedload sampling program in the spring of 2014. This program was subsequently implemented with the help of hatchery and MFLNRO staff.

The bedload data demonstrated that a bedload-discharge rating curve can be established for both the Upper Site and Lower Patch, and summary data are provided below.

Year	Bedload Transport rate (m^3/year)		Suspended Sediment (m^3/year)
	Upper Site	Lower Patch	
2013	1,100	3,400	-
2014	900	2,900	17,500

As shown in the above table, in 2013 and 2014, about 2000 m^3/year more sediment was moved past the Lower Patch than the Upper Site. The 2013-2014 annual load data suggest that each year, 2 to 8 percent of the total amount of bedload introduced by the Cheslatta fan avulsion (> 0.5 mm, 44,000 m^3) moves past the sites. This is a much smaller percentage than estimated in previous reports (NHC, 2013, 2014). The previous analysis were based on BC watershed yield data (NHC, 2013) and a single bedload sample (NHC, 2014), and as such, were less reliable. For example, the 2011 predicted bedload at the Upper Site and the Lower Patch is 10,600 and 28,400 m^3, respectively. Also, the 2012 predicted bedload at the Upper Site and the Lower Patch is 5,700 and 16,100 m^3, respectively. These volumes are significantly higher than that measured in 2013 and 2014 as shown in the above table. Collection of bedload samples during future high flows will be required to confirm the applicability of the rating curve during high flow years like 2011 and 2012.

Going forward, the bedload sampling program should concentrate on collecting samples immediately after ice clears, as well as at the beginning, midpoint and end of the cold water release period while flows are high and bedload transport rates would be maximum. The cold water release samples are particularly important to collect if transport rates become supply-limited, which would help guide if and how sturgeon habitat sediment mitigation efforts could be implemented, and if a single bedload-discharge rating curve can be used during periods of prolonged high flows.

The suspended sediment data suggest that the majority of the suspended sediments are supplied during the freshet, rather than the cold water release period which has a much larger discharge than freshet. This could be explained by several processes. First, the tributaries are a significant source of fine sediment to the mainstem during freshet and not during the release. Second more bed and/or bank material is mobilized during freshet and not during the release. This suggests that possibly the regulated and greater release flows may be less effective in eroding the bed and banks or mobilizing the previously deposited bed material compared to freshet. Collection of additional data will assist in identifying if this is the case.

As shown in the above table, the measured 2014 total sediment load (bedload and suspended) for the Upper Site and the Lower Patch is 18,400 and 20,400 m^3, respectively. This suggests that the bedload/total sediment load ratio was 5% for the Upper Site and 14% for the Lower Site. These values straddle the 10/90 percent split between bed and total loads that is commonly expected in gravel-bed rivers such as the Nechako River, and suggest that the bedload transport rates are not out of step from the suspended sediment load. The outlet of Murray Creek and Stoney Creek are located between the Upper Site and the Lower Site. Suspended sediment may therefore be higher at the Lower Site due to the input from these creeks. A turbidity sensor was installed on the center pier of the Burrard Avenue Bridge in October 2014 to collect data representative of the main Nechako River. This sensor is in addition to an existing one located on the left bank of the river which was more directly influenced by the suspended sediment from Murray Creek.

Collection of bedload samples and turbidity data from the 2015 freshet and cold water release, especially during break up, will greatly improve our understanding of the overall sediment regime and influence of the tributaries on sediment inputs to the Nechako River. This information will then help determine when sediment is passing the sturgeon spawning locations, and if upland sediment production prevention programs may assist the White Sturgeon Recovery Initiative.

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1 INTRODUCTION

Recruitment failure of the Nechako white sturgeon has been linked to substrate changes in the spawning reach (McAdam et al., 2005). As part of ongoing evaluations of the recovery approaches in May 2011, the Ministry of Forest, Lands and Natural Resource Operations (MFLNRO) placed substrate in two locations in the Nechako River at Vanderhoof, BC to improve the availability of clean coarse gravel-cobble substrate at known spawning sites used by white sturgeon (*Acipenser transmontanus*).

Broadcast spawned and fertilized sturgeon eggs are adhesive and negatively buoyant. The eggs drift and fall onto the channel bed, lodging in the substrate. The placed, clean substrate with open, interstitial spaces between the individual gravel and cobble clasts provides improved incubation. Newly hatched larvae and juvenile sturgeon utilize these areas for cover and feeding, with reduced predation and potential increased survival rates (McAdam, 2011). Correspondingly, the interstitial spaces of the channel substrates become filled with fine sediment, the effectiveness of the substrate in terms of cover and feeding habitat is reduced, and larval and juvenile survival is diminished.

In 2011 and 2012 (NHC, 2012, NHC, 2013a), substrate assessments showed that the inside corner of the placed substrate patches was more prone to infilling with gravel and coarse sand than the outside portion of the pads and that coarse sand was mobile at the Burrard Avenue Bridge despite relatively low flows. In 2013, bedload transport sampling investigations further demonstrated that the pattern of transport corresponds well with the observed infilling pattern at the placed substrate locations (NHC, 2014).

Substrate assessments in 2011, 2012 and 2013 have shown that portions of the placed substrate have remained free of fine sediment. However, unpublished observations by Simon Gauthier-Fauteux suggest that fine sediment may move over the entire Lower Patch during some portions of the year. To better understand the transport of suspended sediment, and to help determine if a bedload-turbidity relationship can be used to assess mobility in the Vanderhoof Reach, a turbidity sensor was installed in the fall of 2013 and suspended sediment samples were taken using a D74 sampler and a bridge crane. While such a relationship is likely to be imprecise, few alternative approaches exist given the challenges of continuously monitoring fine gravel and sand transport in rivers like the Nechako**.**

In 2014, the suspended sediment and bedload sampling program was continued. More bedload sampling at different flows and different times of the year were conducted at the Upper Site and Lower Patch sites (

Figure 1) to enable an overall assessment of bedload transport in the area, with the aim to construct a bedload rating curve for each of the sites. Following recommendations from the 2013 study, a Helley-Smith sampler launched from an anchored boat was used to assess bedload transport in the reach. Suspended sediment samples were also taken during April and May of 2014.

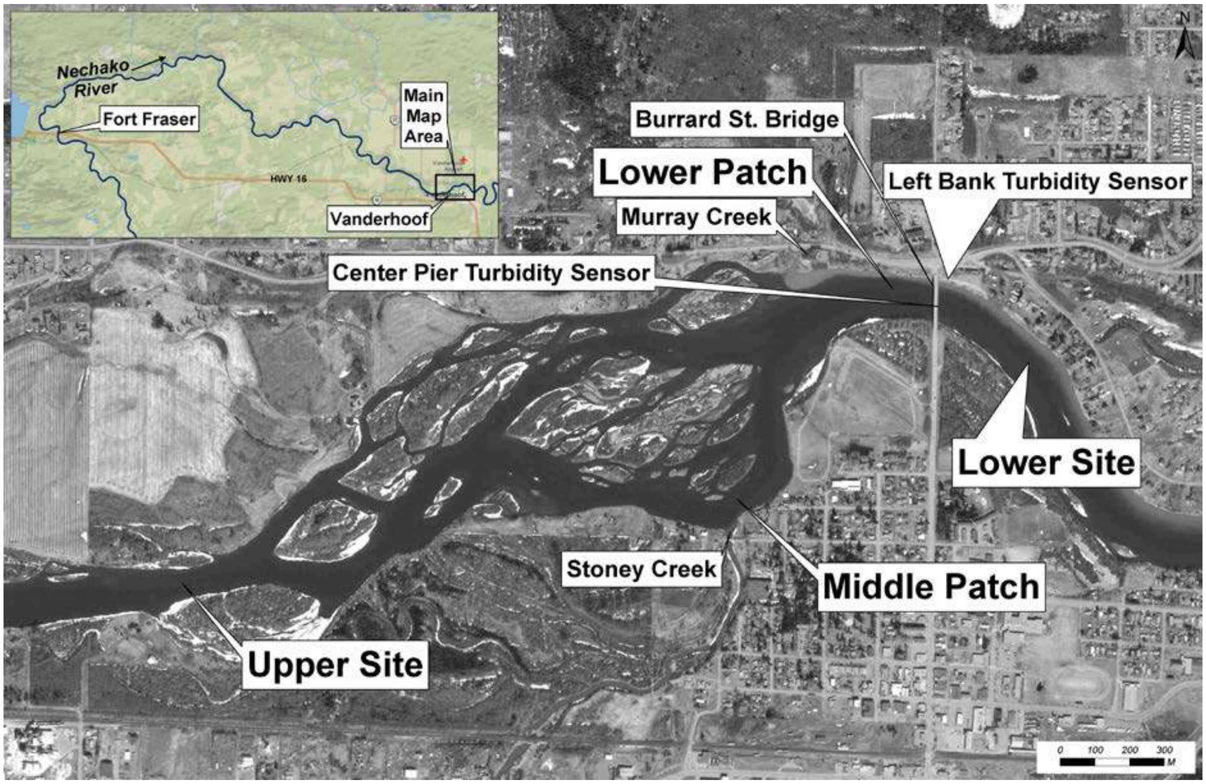

Figure 1 **Overview map of the spawing reach illustrating sampling locations on the Nechako River. Substrate was placed in 2011 at the Middle and Lower Patch. The Upper and Lower Sites are composed of native substrate.**

1.1 BACKGROUND

Development of the Kemano Project in the early 1950's altered the flow regime throughout the Nechako River. Past studies (e.g. NHC, 2002, 2006, 2009) have identified the major geomorphic changes to be vegetation encroachment, the loss of seasonally wetted floodplain and floodplain channels, a reduction in the ability to transport locally recruited and externally-supplied sediment, the mass mobilization and deposition of sediment from the Cheslatta Fan avulsions, and an increase in flow through the Murray-Cheslatta system.

In conjunction with the changes in flow and sediment supply, there has been a reduction in juvenile white sturgeon production. The low number of juvenile sturgeon has been attributed to changes in spawning habitat, and in particular, the infilling of spawning beds with fine sediment (McAdam et al., 2005). A critically important spawning reach has been identified at Vanderhoof and a series of investigations have been conducted to assess the historical and contemporary characteristics of the reach (NHC, 2006). These investigations have revealed the following (as summarized in NHC, 2012):

1. The spawning reach (Figure 1) occurs at a distinct reduction in channel gradient (0.06% upstream to 0.03% downstream (NHC, 2006)).
2. The substrate at the top of the reach is cobble-gravel while the substrate at the downstream end of the reach is gravel-sand.

3. The construction of the south causeway to the Burrard Avenue Bridge, which occurred prior to 1928, eliminated floodplain conveyance and reduced the conveyance width to 150 m. This has promoted the deposition of finer sediment and larger quantities of sediment upstream of the bridge (NHC, 2006).
4. The Cheslatta fan avulsions that occurred between the late 1950's and 1972 introduced 0.86 to 1.1 million cubic meters of sediment to the Nechako River (NHC, 2009).

In summary, the spawning reach at Vanderhoof is located in an area with a marked change in channel gradient that promotes the deposition of sand and gravel sediment that originates from the upstream watershed. Flow regulation and channel confinement have likely increased the deposition of sediment in the reach. This indicates a general agreement with the hypothesized negative effect of fine substrate deposition on recruitment and suggests that understanding the sediment dynamics is critical to recovery action.

1.2 Study Rationale and Approach

This report and the associated field studies are intended to partially address the following research question. What are the modes, pattern, magnitude and timing of sediment transport over the placed substrate?

For the purposes of this report, grain size classification is based on the length of the b-axis, or the intermediate axis perpendicular to the longest axis. Grain size texture is defined using the Wentworth scale (Table 1). This size classification can be expressed as a negative base two exponential where the exponent is referred to as phi (e.g. 2^{φ}). A ½ phi scale is where the exponent varies by 0.5 intervals rather than 1.

Table 1 Wentworth grain size scale.

Length of b axis (mm)	ϕ (phi)	Wentworth grain size scale
>256	<-8	Boulder
64 - 256	-6 – -8	Cobble
32 - 64	-5 – -6	Very Coarse Gravel
16 - 32	-4 – -5	Coarse Gravel
8 - 16	-3 – -4	Medium Gravel
4 - 8	-2 – -3	Fine Gravel
2 - 4	-1 – -2	Very Fine Gravel
1 - 2	0 – -1	Very Coarse Sand
0.5 - 1	1 – 0	Coarse Sand
0.25 - 0.50	2 – 1	Medium Sand
0.125 - 0.250	3 – 2	Fine Sand
0.064 - 0.125	4 – 3	Very Fine Sand
0.0039 - 0.064	5 – 4	Silt
<0.0039	> 5	Clay

2 METHODS

In 2014, regular measurements of bedload sediment transport at the Lower Patch and Upper Site locations were conducted by local MFLNRO staff based on sampling methodologies established by NHC staff during an initial site visit. Bedload sampling was conducted at the Upper Site and Lower Patch locations on 12 separate days beginning in April and continuing through August.

The August bedload sampling was during the cold water release from the Skins Lake Spillway and represented the higher end of flow experienced annually. Suspended sediment sampling was conducted at the Burrard Avenue Bridge during freshet. The sampling collected a range of turbidity values over three days in April to capture the earlier freshet in the tributaries and in May to capture the later main freshet on the Nechako River. While suspended sampling was attempted later in the year, problems with the bridge crane prevented samples from being collected. Nevertheless, at these times turbidity values were low, and as a result the data were not critical to the overall program.

2.1 BEDLOAD SAMPLING

Bedload sediment sampling was conducted at two sites, Upper Site and Lower Patch. At each site, a transect was established across the channel and several stations were sampled at evenly spaced intervals across the channel. A detailed sampling program was developed in April of 2014 and is provided in
Appendix A along with blank data sheets.

In brief, a Helley-Smith sampler (Figure 2) with a 76.2 mm wide opening and 0.125 mm mesh bag was used to monitor sediment transport rates. In general one sample was collected from each vertical over a duration of 5 minutes. To deploy the sampler, the boat was held in place using an anchor and the sampler was slowly lowered onto the bed. The cable was left slack and monitored to ensure there was no risk of the sampler being dragged due to lateral boat movement.

At the Upper Site, characterized by a fairly straight channel and fairly uniform cross section, a sampling transect was established that runs roughly through the middle of the site. The bed material at this site is primarily cobble with sand and gravel mixed into the interstices. At Lower Patch, the sampling transect was established across the upstream portion of the patch**.** The left outside section of the channel is deep and has a cobble bed, which is placed material. The right inside section of the channel is relatively shallow and is a mixed sand and gravel bed.

2.2 SUSPENDED SEDIMENT SAMPLING

Suspended sediment samples were collected with a Bridge Crane and D-74 depth integrating sampler (Figure 3). In April 2014, a suspended sediment sampling program was developed and the details are provided in Appendix B. In brief, the samples were collected with a Bridge Crane and D-74 depth integrating sampler. The crane and sampler are shown in Figure 3. The winch on the crane, known as a B-reel, uses a brake shoe that is pressed against a brake pad to control the rate of descent. To raise the sampler, the crank is used to retract the cable.

Figure 2 Photo showing the Helley-Smith sampler and crane mount that were used.

Figure 3 Bridge Crane with suspended sediment sampler and B-reel.

3 SEDIMENT TRANSPORT ANALYSIS

3.1 BEDLOAD SEDIMENT TRANSPORT

Bedload samples were individually labeled and sieved at the UBC Geography Department using ½ phi sieves. Total instantaneous bedload sediment transport rates for each site were calculated using the mid-section approach and the results are summarized in Table 2. Complete results are provided in Appendix C.

Table 2 Bedload Sediment Transport Field Measurements

Date	Upper Site (g/s)	Lower Patch (g/s)
15-Aug-13	186	5793
11-Oct-13	1	4
26-Apr-14	88	422
27-May-14	60	661
28-May-14	50	334
10-Jul-14	6	47
15-Jul-14	7	115
18-Jul-14	50	82
21-Jul-14	373	237
23-Jul-14	104	219
24-Jul-14	143	585
13-Aug-14	536	157

To develop a better understanding of the annual bedload transport rate, preliminary rating curves were developed using discharge as an indicator of bedload transport (Figure 4 and Figure 5). The discharge data from the Water Survey of Canada (WSC) are preliminary, and the most recent measurements were more than 10% off from the current WSC curve. To enable a more accurate discharge time series NHC imported the discharge measurements and stage data from the real-time WSC website and created a new rating curve (Figure 6).

Since the WSC did not made any discharge measurements during the August cold water releases in 2013 or 2014, NHC also utilized their discharge measurements from August 2013 to modify the curve. A shift in the curve from July 30th forward was applied to account for the apparent aggradation of the section during the 2014 cold water release period. The preliminary discharge time series for 2013-2014, based on NHC's curve, is shown in Figure 7. The preliminary 2013 and 2014 data were also corrected for ice effects. Additional flow measurements during the cold water release program should be made by NHC or WSC in 2015 to validate the curve at higher flows.

The bedload-discharge rating curves were used to predict bedload transport rates for the period of record. The 2013 and 2014 period is summarized in Figure 8 and Figure 9 along with the field measurements. Annual rates of bed and suspended load transport are summarized in

Table 3. With respect to Figures 8 and 9, the difference between the measured and predicted bedload for August 2013 is quite significant. For the Upper Site the measured rate is 1/3 the predicted and at the Lower Patch the measured rate is about 3 times the predicted. The 2013 measured data is based on just one sample. Additional August sampling in future years will help identify if this August 2013 sample was an anomaly and it will also help determine the accuracy of the rating curves. Also note that the variability about the rating curve, when viewed in log space, is as much as a factor of 5 or 7 across the full range in flows (Figure 4 and Figure 5). In linear space the variability appears much larger at the high flows (Figure 8 and Figure 9).

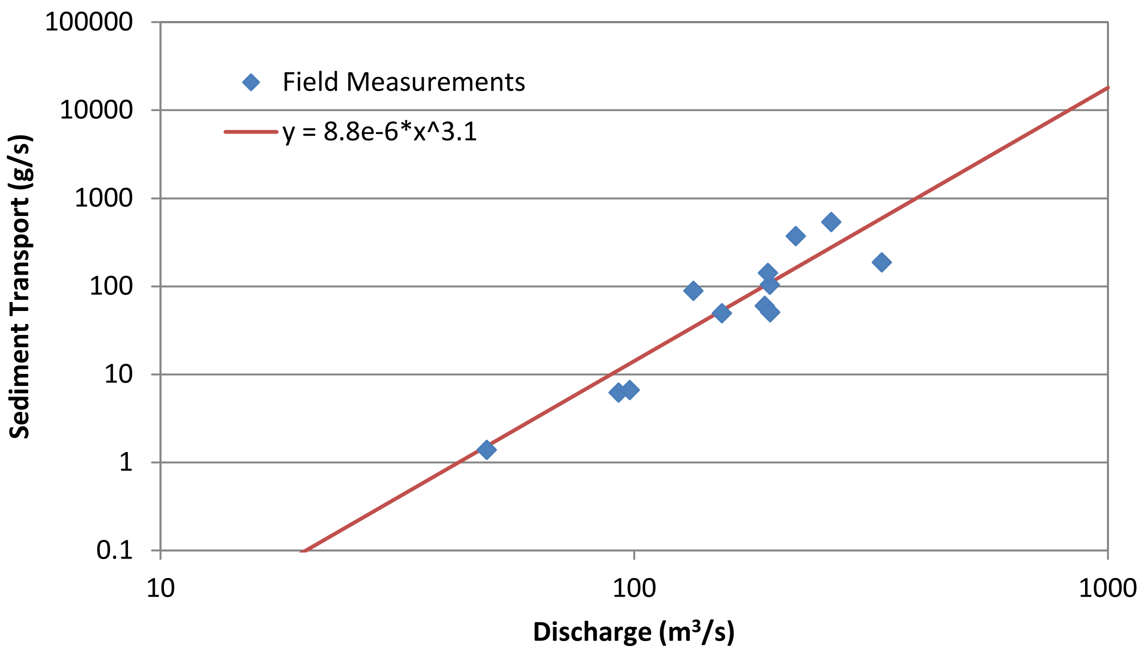

Figure 4 Rating curve for bedload sediment transport at Upper Site.

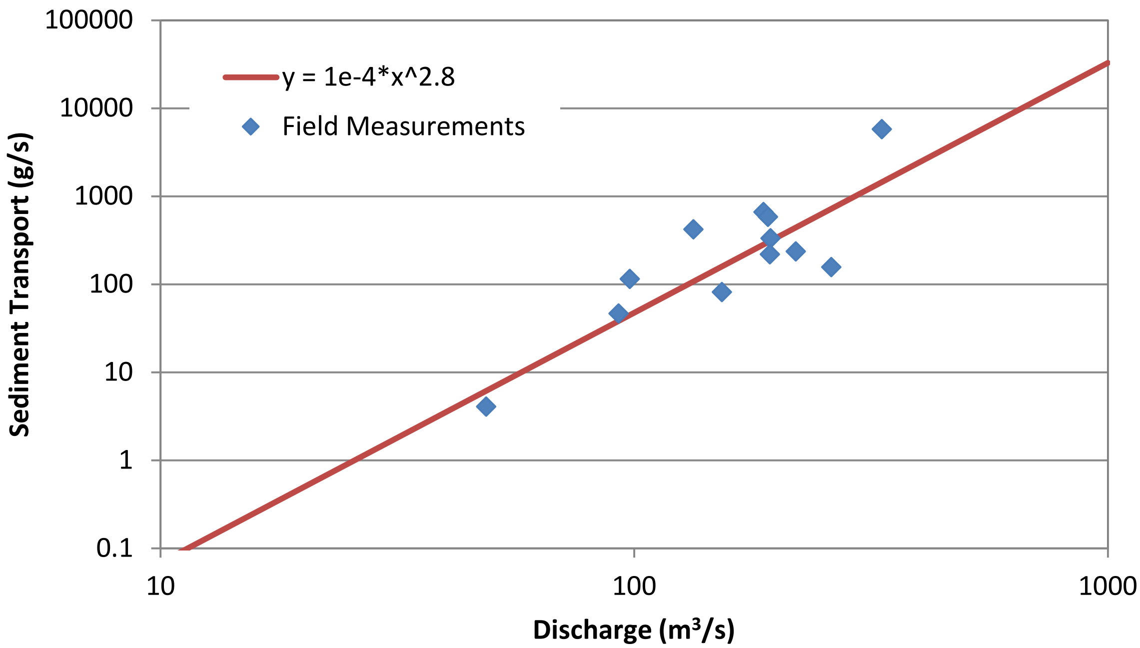

Figure 5 Rating curve for bedload sediment transport at Lower Patch.

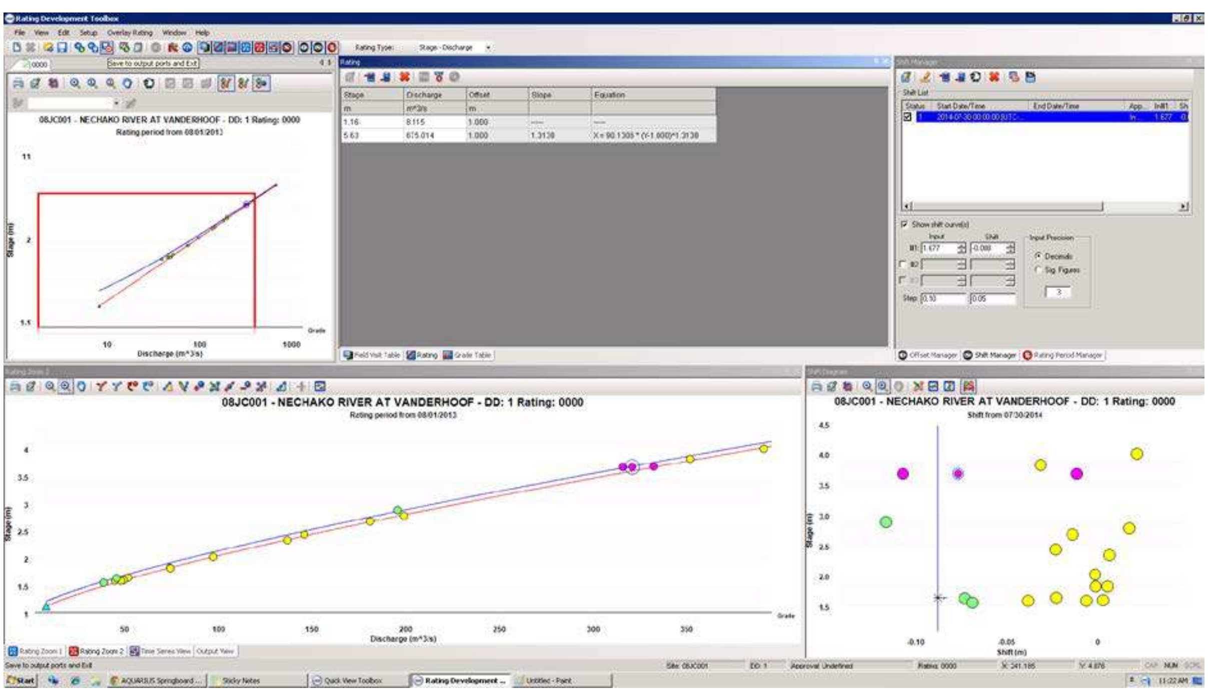

Figure 6 NHC rating curve with shift for WSC gauge at Vanderhoof.

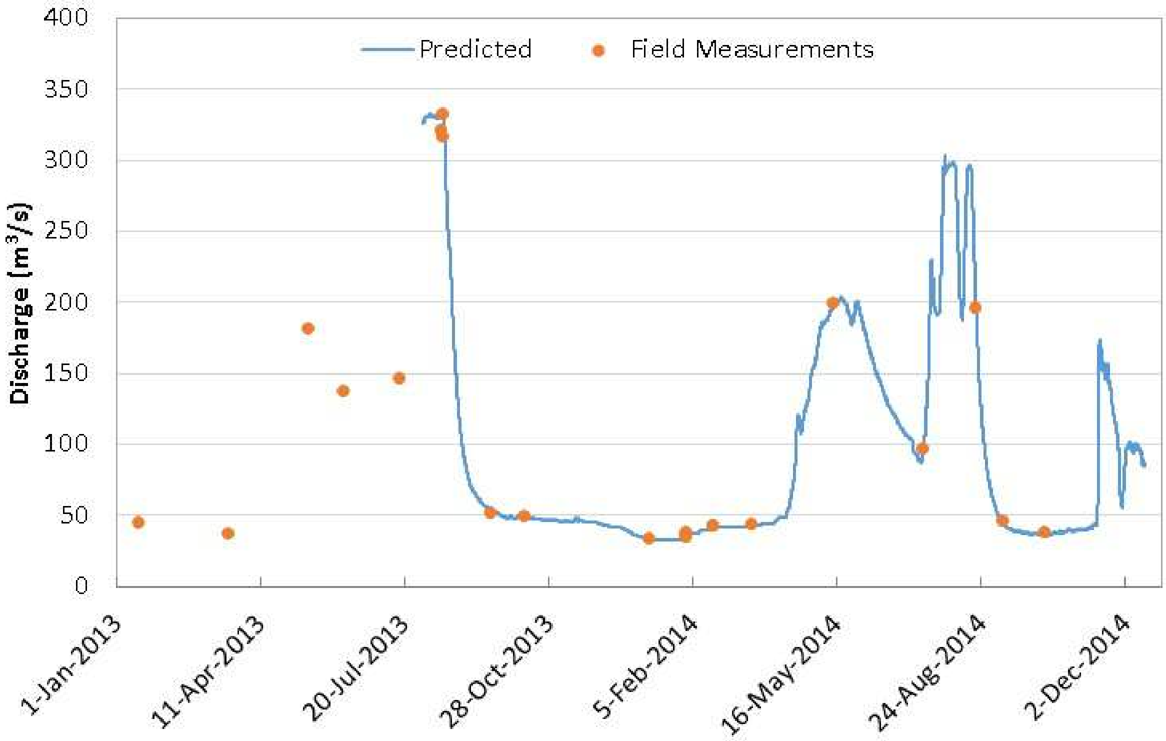

Figure 7 Discharge time series for 2013 and 2014 based on NHC rating curve with shift.

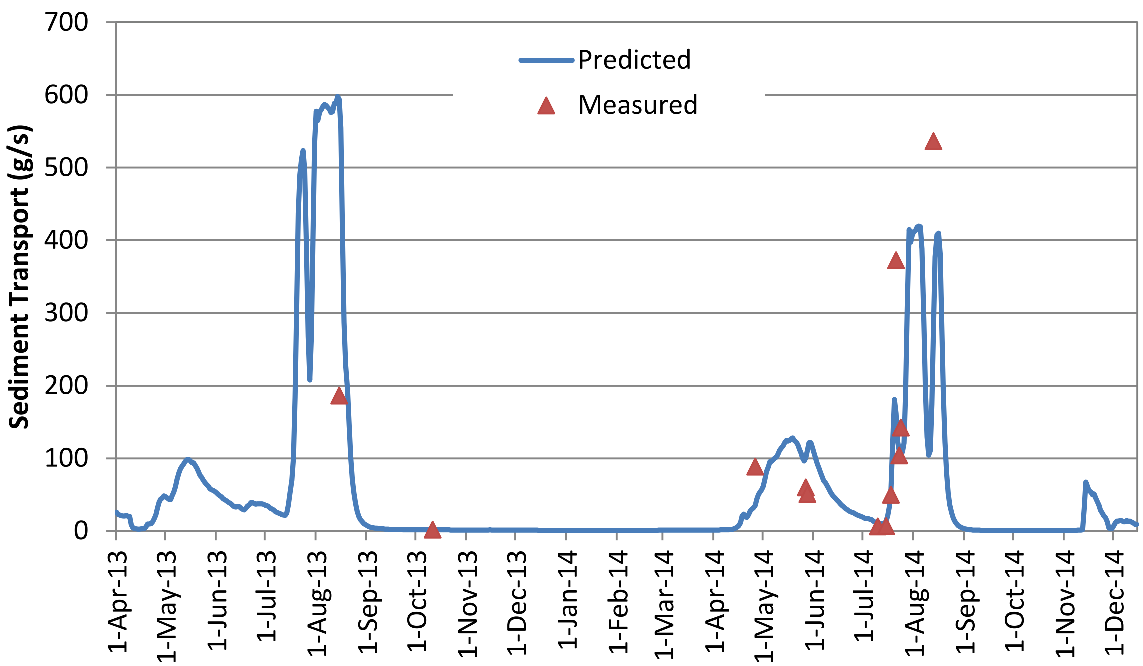

Figure 8 Bedload sediment transport at Upper Site.

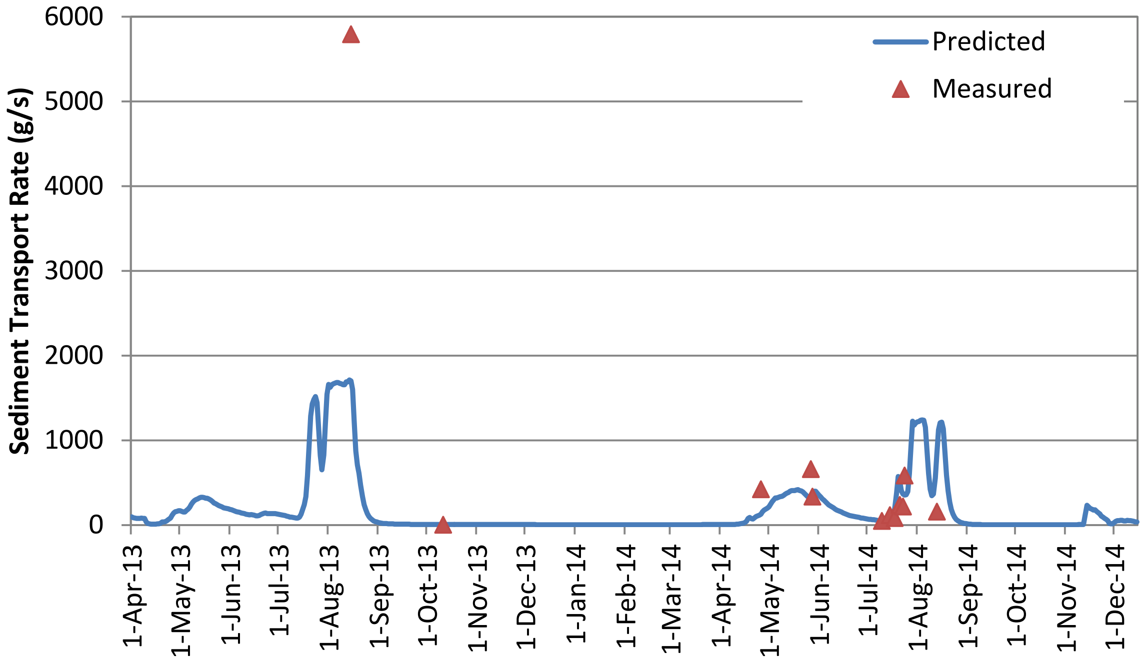

Figure 9 Bedload sediment transport at Lower Patch.

To attain an initial assessment of the annual bedload transport rate, the daily discharge record from 1957 to present, along with the current rating curve, were used. In practice, this approach becomes increasingly inaccurate when going back in time, as the bedload-discharge rating curve has likely varied with time and the bedload sediment transport regime may become supply-limited at sustained, higher flows.

Summary data for the period are presented in

Table 3 including the average from 1957 to 2013 as well as individual years for 2011 to the end of 2014. The analysis suggests that a much larger than average volume of bedload sediment may have moved through the Vanderhoof Reach in 2011 and to a lesser extent in 2012. However, no field measurements of bedload sediment transport were done during those years. A comparison of the predicted bedload transport rates at the Upper Site and Lower Patch shows that about 3 times more material is moving at the Lower Patch, than through the Upper Site. Over the long term, this difference of three times is not sustainable. Therefore it is possible that during periods when samples have not been collected, bedload may be moving past the Upper Site and not past the Lower Patch and hence temporarily stored between the sites in the island complex. The most plausible time for unaccounted transport would be during the rising limb of the cold water release period, or during the higher flows that occurred in 2011 and 2012. The addition of Murray Creek and Stoney Creek between the two sites may account for additional sediment past the Lower Patch but based on the nature of these creeks the input is likely relatively low and probability more related to suspended sediment than bedload.

Table 3 Predicted and measured bedload and suspended sediment yield (m^3 per year).

Period	Upper Site Bedload	Lower Patch Bedload	Suspended Sediment at Burrard Bridge
Average 1957-2013	3,800	10,300	
2011	10,600	28,400	
2012	5,700	16,100	
2013	1,100	3,400	
2014	900	2,900	17,500

A more systematic, focused sampling program in 2015 should be done to examine if transport rates are consistently greater on the rising limb of the cold water release compared to the falling limb, as this would indicate if the system becomes supply limited.

3.2 SUSPENDED SEDIMENT TRANSPORT

Suspended sediment samples were processed at the UBC Geography Department and the results are summarized in Table 4. The sediment samples were sieved at phi intervals and the data are summarized in Appendix D. To calculate the mean concentration across the river, the samples were weighted by the volume of water collected, as the vertical sampling velocity was held constant during each measurement.

Average across-channel concentrations were plotted against turbidity data downloaded from the left bank sensor to develop a turbidity-suspended sediment rating curve (Figure 10). A plot showing the predicted concentration over time, along with the field visits, is shown in Figure 11. The turbidity record from October 10th 2013 to October 10th 2014 was used to determine the average annual suspended sediment concentration. These data where then used with the discharge time series to determine the annual suspended sediment load in 2014 (

Table 3).

Table 4 Suspended Sediment Field Measurements.

Date	Suspended Sediment Concentration (mg/L)
12-Oct-2013	3
25-Apr-2014	22
25-Apr-2014	23

28-May-2014	8

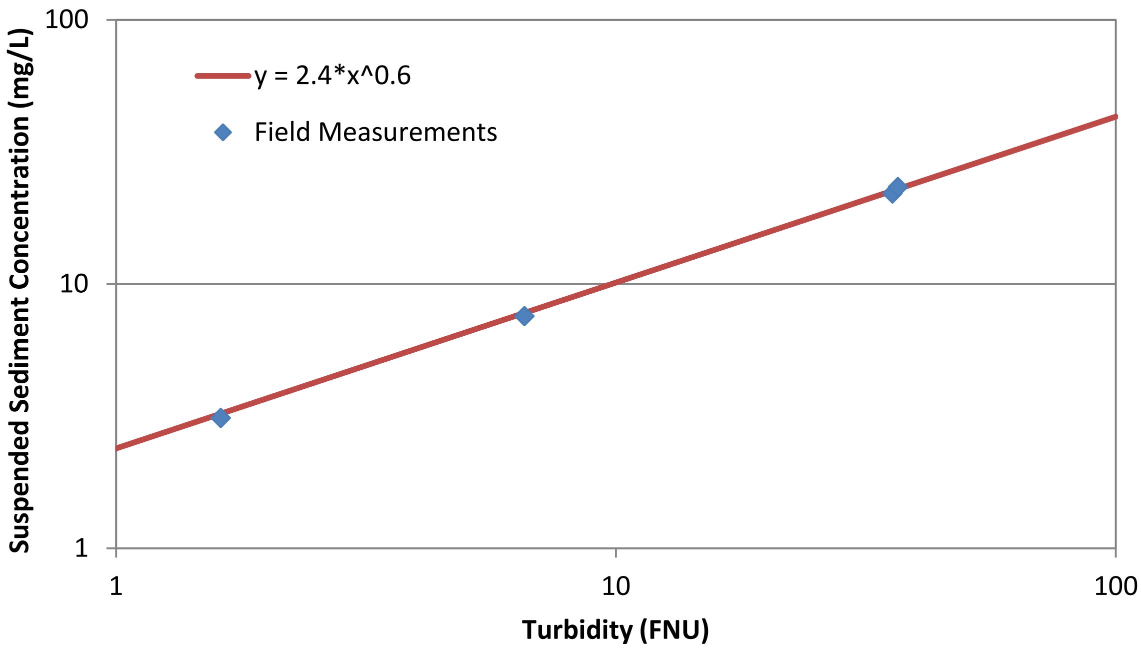

Figure 10 Rating curve for suspended sediment transport.

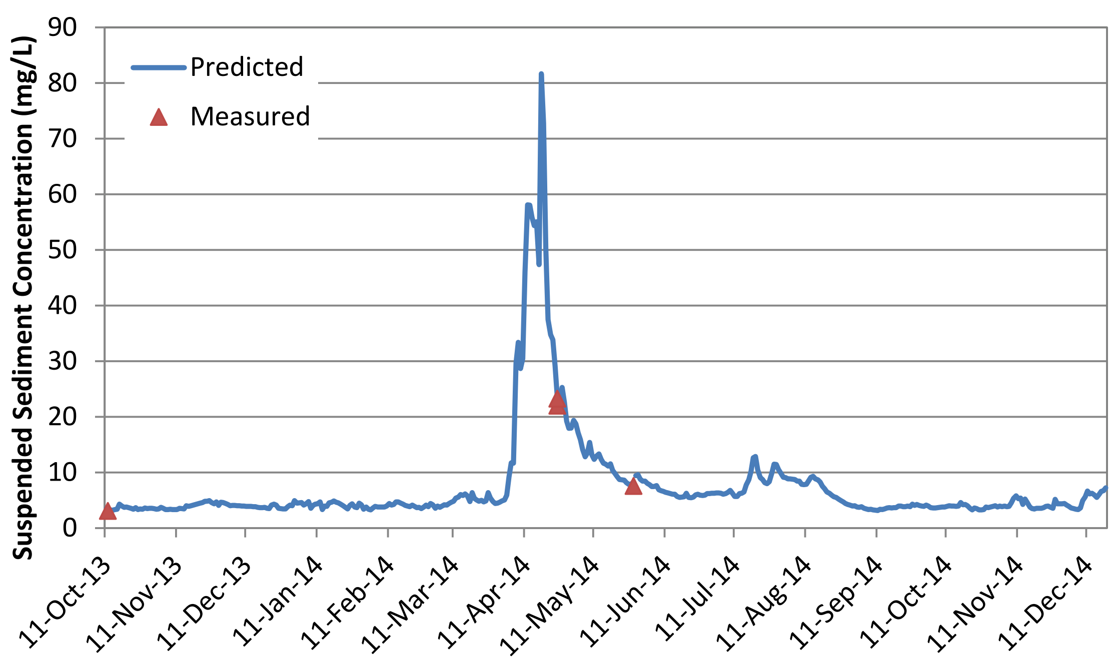

Figure 11 Suspended sediment concentration.

3.3 INTERPRETATION AND ANALYSIS

Figure 12 provides a simple overview of the seasonal and annual sediment transport patterns at Vanderhoof. The data suggest that the spring freshet contributes a large amount of suspended sediment to the system, despite the relatively low discharge during the period (Figure 7).

The accuracy of these data are questionable, however, as Murray Creek, located immediately upstream on the same side of the river as the sensor, could be biasing the turbidity data and resulting in an artificially high turbidity signal. To overcome this potential bias a second Analite® turbidity sensor was installed in October 2014 on the south side of the middle pier of the bridge Figure 13). To date, the sensor is providing high quality data and appears to be less susceptible to fouling. Freshet data from 2015 will improve our understanding of across channel variability in turbidity, which will be backed up by suspended sediment samples.

The bedload data suggests that transport rates are about three times greater at the Lower Patch than the Upper Site. Figure 12 however shows that the sampling in 2014 missed the main high flow periods associated with the cold water release. The 2015 sampling program needs to target the cold water release period and collect samples during the beginning, middle and end of the high flows associated with the cold water release.

The preliminary data suggest that about 2,000 m^3 of additional material passed through the Lower Patch in 2014 compared to the Upper Site. This is a relatively small amount, which could be attributed to within channel storage, and the amount was similar in 2013 (2,300 m^3). Larger differences in transport volumes were predicted for 2011 and 2012, but it is unclear if the rating curve applies to these periods.

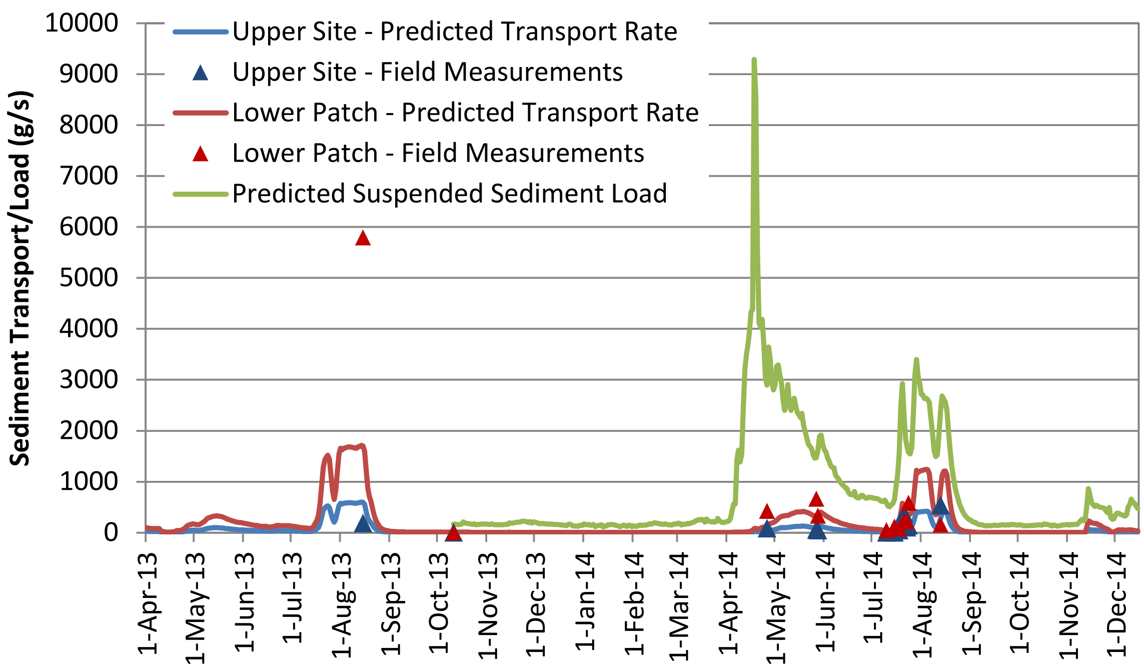

Figure 12 Summary figure of transport rates and suspended sediment load.

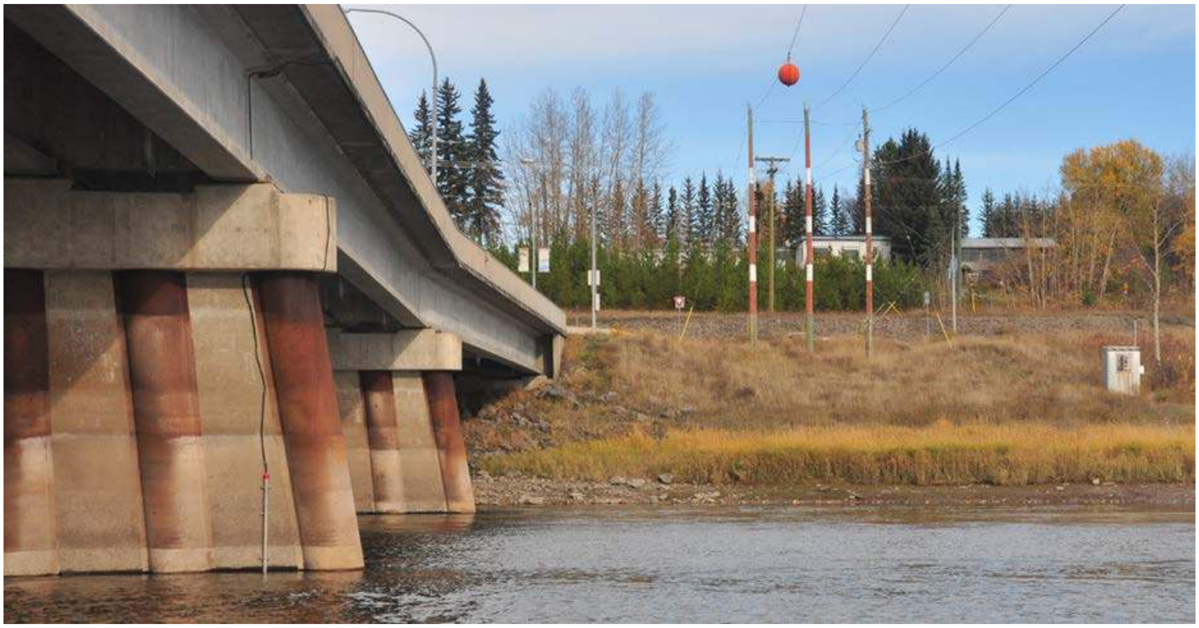

Figure 13 Turbidity sensor installed on middle pier of Burrard Avenue Bridge.

4 CONCLUSIONS AND RECOMMENDATIONS

The bedload sampling program in 2013-2014 demonstrated that a bedload-discharge rating curve can be established for both the Upper Site and Lower Patch. The bedload-discharge curve suggests that more sediment is moving at the Lower Patch and less at the Upper Site than the first order estimates provided in 2013. The revised data are considered far more reliable, but still need refinement based on measurements at higher flows.

The most recent analysis suggests that about 2,000 m^3 per year more sediment was moved past the Lower Patch than the Upper Site in 2013 and 2014. The 2013-2014 annual bedload data suggest that the annual loads moving past the Lower Patch and Upper Site are on the order of 2 to 8 percent of the total amount of bedload introduced by the Cheslatta fan avulsion (> 0.5 mm, 44,000 m^3). This is a much smaller percentage than estimated in previous reports (NHC, 2013, 2014). The previous analysis was based on BC watershed yield data (Church *et al*., 1989) and a single bedload sample (NHC, 2014), and as such, are less reliable. For example, the 2011 predicted bedload at the Upper Site and the Lower Patch is 10,600 and 28,400 m^3, respectively. Also, the 2012 predicted bedload at the Upper Site and the Lower Patch is 5,700 and 16,100 m^3, respectively. These volumes are significantly higher than that measured in 2013 and 2014 as shown in Table 3. Collection of bedload samples during future high flows will be required to confirm the applicability of the rating curve during high flow years like 2011 and 2012.

In future years, the bedload sampling program needs to concentrate on getting samples immediately after ice-off and break-up, as well as at the beginning, midpoint and end of the cold water release period while flows are high. These are particularly important in accessing if transport rates become supply limited, which would help guide if and how sediment supply mitigation efforts could be implemented and if a single rating curve can be used during periods of prolonged high flows.

The suspended sediment data suggest that the majority of the suspended sediment are supplied during the freshet, rather than the high flow cold water release period. This suggests that the tributaries are an important source of fine sediment to the mainstem, the channel may be sufficiently armored to prevent significant erosion and entrainment of finer sediments from the cold water release flows, and/or the flows are not large enough to erode and transport existing bank and bed materials on the mainstem.

As shown in Table 3, the measured 2014 total sediment load (bedload and suspended) for the Upper Site and the Lower Patch is 18,400 and 20,400 m^3, respectively. This suggests that the bedload-to-total load ratio for 2014 was 5% for the Upper Site and 14% for the Lower Patch. These values straddle the 10/90 percent split between bed and total loads that is commonly expected in gravel-bed rivers, and suggest that the bedload transport rates are not out of step from the suspended sediment load. However, the suspended sediment load may be positively biased due to the influence of Murray Creek. Data from the 2015 freshet, especially during break up, will greatly improve our understanding of the overall suspended sediment regime and the influence of tributaries on sediment inputs to the Nechako River.

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NHC (2014). *Nechako River 2013 Sediment Transport Investigations*. Prepared by Northwest Hydraulic Consultants for the Ministry of Forests, Lands and Natural Resource Operations, North Vancouver BC. 48 pp.

Appendix A Bedload Sampling Procedures

MEMORANDUM

TO:	Zolt Sary, R.P. Bio (MFLNRO)	**DATE:**	December 29, 2014
FROM:	Andre Zimmermann (NHC)	**NO. PAGES:**	6
CC:	Tim Argast (NHC)	**PROJECT NO.:**	300357
		REF. NO.:	

RE: **Nechako White Sturgeon Recovery Initiative**
Bedload Sampling Procedures
DRAFT

Overview

The intent of this memo is to provide a simplified explanation of how to collect bedload sediment samples in the Vanderhoof reach of the Nechako River. A detailed description of the approach and theory is available in other publications (Edwards and Glysson, 1988).

The samples will be collected with a Helley-Smith bedload sampler. A Helley-Smith sampler with a 76.2 mm wide opening and 0.125 mm mesh bag is to be used to monitor sediment transport rates. In general one sample is to be collected from each vertical over a duration of 300 seconds (5 minutes). If transport rates are exceptionally high and the bag over-fills, additional samples are to be collected for shorter duration periods.

The sampler on a boat mounted crane is shown in **Figure 1** and an example of collected bedload material is shown in **Figure 2**.

Figure 1: The Helley-Smith sampler suspended from a boat mounted crane.

Figure 2: An example of the bedload captured

Before Heading to the Field

- Check WSC gauge for current water level and discharge (http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=08JC001)
- Assemble Gear

Gear List

- Helley-Smith Sampler
- GPS with coordinates of sampling locations
- Squeezable water bottle
- 20-30 large Ziploc bags (26.8cm x 27.3cm Double Guard Freezer bags)
- Black permanent marker
- Camera
- Field book
- Stop watch
- Two people

To do on Site

- Check that the sample bag and sampler are clean
- **Note who is collecting the samples, date and if Time is being recorded in PDT (local) or PST**
- Begin sampling at the first location where the water depth is sufficient for boat access
- Take a photo of the site that shows conditions of the river at each site. Take photos facing upstream, downstream and of each bank.

Sampling

- Navigate the boat as close as possible to the GPS point (within 5m of the point) and drop the anchor
- Allow the boat to come to rest on the anchor. The amount of rode required will vary dependent on flow but should be around 15m. Record in the field notes an estimate of how much rode is played out
- Attach a clean sample bag on to the Helley-Smith
- Slowly lower the sampler to the river bed. The tail of the sampler should make contact with the bed first followed by the nozzle.
- As soon as the sampler is resting flat on the bed, start the timer.

- Collect sediment for 300 seconds (5 minutes)
- During sediment collection **it is essential that the cable to the sampler remains slack and the boat does not pull on the sampler** causing it to dredge up material. If this occurs, the sampler should be brought to surface, the sample bag flushed clean, and the collection started again.
- As soon as 300 seconds has been reached, the sampler should be raised back to the surface.
- **Check if the sample has an unexpected amount of sediment in it. This could indicate that the sampler nose-dived into the bottom or was dragged along the bed. If this is suspected of occurring flag the sample and collect an additional sample. If you are confident this happened, discard the sample and collect another sample.**
- Bedload transport is highly variable in space and time so adjacent locations may collect very different amounts. Make notes on any observed sheets or streams of mobile bed material.
- Check that the sample bag is not over-filled (>40% full of fine sediment)
- Using the squeezable water bottle, wash any sediment that is stuck in the opening or upper parts of the sample bag into the back of the bag.
- Carefully transfer the sediment from the sample bag to a Ziploc. Use the water bottle to wash the sediment stuck to the collection bag, and then carefully drain off the excess water from the Ziploc.
- Label the Ziploc with the site and station number, the length of the sample, and the date and time. If multiple samples were taken for one station, this should also be included.
- If the sample bag is more than 40% full, it is likely that the hydraulic efficiency of the sampler has been reduced and a biased sample has been collected (Emmett, 1980). The sample must be discarded and a new sample collected.
- If the bag is only slightly over-filled, attempt to collect two samples of 150 seconds or three samples for 100 seconds. Having a total of 300 seconds of capture per station greatly decreases the amount of analysis required.
- If the station has particularly high transport rates, a single sample may be collected but should be avoided to simplify the analysis. **It is essential that sample durations less than 300 seconds be recorded and marked for separate analysis.**
- If there is a tiny bit or no sediment, the sample from the next vertical can be included. In this case don't replace the bag but just go to the next location. This is likely only suitable if sampling during low river discharge.
- With each sample **record the site location, station number, sample time and duration in the field book.**

POST SAMPLING

- **Rinse the sampler and sample bags**
- **Allow sampler and bags to dry**
- **Put sampler and bags back in box**
- **Take a photos or scan all field notes**
- **Email targast@nhcweb.com and azimmermann@nhcweb.com a copy of the field notes and the photos.**
- **Put samples in their own Rubbermaid container and arrange for them to be shipped.**
    - **Currently these should be sent**
    - **Northwest Hydraulic Consultants**
    - **ATTN: Tim Argast/Andre Zimmermann**
    - **30 Gostick Place**
    - **North Vancouver**
    - **V7M 3G3**
    - **604-980-6011**
    - **This may be updated once we figure out who will be processing the samples at UBC.**

*   *   *   *   *

If you have any questions, please do not hesitate to contact me at 604.980.6011.

Sincerely,

northwest hydraulic consultants ltd.

Andre Zimmermann P.Geo. (NHC)

References

Edwards, T. K., and Glysson, D. G. (1988). *Field methods for measurement of fluvial sediment* (Open File Report 86-531). U.S. Geological Survey, Reston, Virginia. 132 pp.

Emmett, W. W. (1980). *A field calibration of the sediment traping characteristics of the Helley-Smith bedload sampler*. United State Geological Survey.

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Appendix B Suspended Sediment Sampling Procedures

MEMORANDUM

TO:	Zolt Sary, R.P. Bio (MFLNRO)	**DATE:**	May 13, 2014
FROM:	Andre Zimmermann (NHC)	**NO. PAGES:**	7
CC:	Tim Argast (NHC)	**PROJECT NO.:**	300357
		REF. NO.:	

RE: **Nechako White Sturgeon Recovery Initiative**
Suspended Sediment Sampling Procedures
DRAFT

OVERVIEW

The intent of this memo is to provide a simplified explanation of how to collect suspended sediment samples from the Burrard Avenue Bridge in Vanderhoof. A detailed description of the approach is available in other publications (Edwards and Glysson, 1988; Tassone et al., 1993).

The samples will be collected with a Bridge Crane and D-74 depth integrating sampler. The crane and sampler are shown in Figure 1 and Figure 2. The B-reel uses a break shoe that is pressed against a break pad to control the rate of decent. To raise the sampler crank in the clockwise direction.

The sampler should be outfitted with a ¼” nozzle (largest one) and a flat head screw drive is use to install the mounting rod (Figure 3). The plastic bottles are inserted into the sampler as far as possible and the door is closed while holding the rim of the sampler down so as to not displace the bottle upwards. DO NOT STORE SAMPLER WITH A BOTTLE INSIDE. This can cause the seal to become permanently compressed.

Figure 1: Bridge Crane with suspended sediment sampler and B-reel

Figure 2: Top half of Bridge Crane and Suspended sediment sampler (note wires rapped in red tape where subsequently lowered to allow the sampler to be raised higher)

Figure 3: Suspended sediment sampler with nozzle installed and mounting bar installed

Before Heading to the Field

- Check WSC gauge for current water level (http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=08JC001)
- Enter current water level in excel spreadsheet so that sampling depths are automatically calculated.
- Print data sheet, consider using waterproof paper if weather forecast is for wet conditions.
- Assemble Gear

Gear List

- Sampler
- Bridge Crane
- 20-30 empty water bottles with lids
- Labels
- Black permanent marker
- Printed off field data sheet with current stage data
- Camera (or cell phone)
- Rope and red ball to indicate sampler is present
- Stop watch
- Two people

To do on Site

- Check that nozzle is clear of material
- Check that drain hole in bottom of sampler is clear of material
- Walk to far end of bridge (left bank, away from boat launch) pulling the sampler and bridge crane.
- Determine where the edge of water is to the nearest meter and **record on field sheet**. The black electrical tape on the bottom of the railing is at 5 meter spacing and starts at the left end of the railing. See field sheet for red and black tape convention.
- **Note who is collecting the samples, date and if Time is being recorded in DST (local) or PST**
- Begin sampling at the first location where the water depth is sufficient (greater than 0.3 m). Typically this will be at the 25 or 30 m point

- Before putting a water bottle in the sampler, lower it so the nozzle is at the water surface. Then adjust the bridge crane depth reel so it is reading zero. **(I don't have a photo of what zero is, the first time you do this, take a photo and send it please).** This will set it up so you always are starting to sample at zero

SAMPLING

- Stick label on sample bottle
- Fill in label on sample bottle (date, time, vertical (distance across channel) and river)
- Put bottle in sampler
- Move sampler to correct position along the bridge and tip the crane against the railing. Watch the crane isn't sitting on the railing.
- Lower sampler to within 1 meter of water surface.
- Start descending at selected rate (0.15 m or 0.2 m per second, see data sheet).
- When the sampler gets to zero the person running the **Timer should hit start and say zero**
- Then **Timer should count out the seconds**
- **Winch operator should keep an eye on decent rate and target depth**, once the bottom/target depth is reached the winch operator should quickly switch directions and come back to the surface at the **same rate.**
- The **Timer should stop the clock when the sampler reaches zero.**
- Winch the crane to the top so that it can clear the bridge rail
- The bridge crane should then tilted back up right
- Hold the tail of the sampler down and then open the top.
- **CHECK IF THE BOTTLE IS OVER FILLED: IF WATER IS TO THE RIM, THEN IT IS OVER FILLED, if it is just below the rim, likely over filled, should be down about 1 "**
- **Check if the sample has an unexpected amount of sediment in it. This could indicate that the sampler hit the bottom and stirred sediment into suspension or the nozzle hit the bed. If this is suspected of occurring flag the sample and collect an additional sample. If you are confident this happened, discard the sample and collect another sample.**
- If bottle is over filled, empty bottle and put back in case. Later the bottle will need to be rinsed with filtered or distilled water till it and the lid is clean. Take label off at this point
- If sample is good, take a lid from a new unused sample and put it on the current sample.
- Swap out bottles.

- If there is a tiny bit of water, (1/4 to 1/3 or less), the sample from the next vertical can be included. In this case don't replace the bottle but just go to the next location. This is likely only suitable at the 120-150 m locations where depths are shallow and velocities are slow.
- With each sample **record the sample time and duration on the field sheet.**
- Record the position of the water surface on the right bank.

POST SAMPLING

- **Take a photo of the site that shows relative clarity of water.**
- **Put 3 drops of Copper Sulfate (0.05%) in each sample**
- **Remove nozzle, check that it is straight and unobstructed**
- **Put bridge crane back in storage. If wet, let it dry completely before putting it in un-heated storage**
- **Put sampler back in box**
- **Take a photo of the field sheet and any additional notes**
- **Email targast@nhcweb.com and azimmermann@nhcweb.com a copy of the field notes and the photos.**
- **Put samples in their own Rubbermaid container and arrange for them to be shipped.**
    - **Currently these should be sent**
    - **Northwest Hydraulic Consultants**
    - **ATTN: Tim Argast/Andre Zimmermann**
    - **30 Gostick Place**
    - **North Vancouver**
    - **V7M 3G3**
    - **604-980-6011**
    - **This may be updated once we figure out who will be processing the samples at UBC.**

*   *   *   *   *

If you have any questions, please do not hesitate to contact me at 604.980.6011.

Sincerely,

northwest hydraulic consultants ltd.

Andre Zimmermann P.Geo. (NHC)

REFERENCES

Edwards, T. K., and D. G. Glysson (1988), Field methods for measurement of fluvial

Tassone, B. L., L. Francois, and P. Zrymiak (1993), Field Procedures for Sediment Data Collection: Volume I - Suspended Sediment, Environment Canada, Ottawa, pp. 38.

Appendix C Bedload Sediment Transport Data

Date Sample Collected	Sample Name	Transport Rate (g/s/section)	Cumulative Percent Finer Than; Grain size classes are in mm																					
			45	32	23	16	11	8	5.7	4	2.8	2	1.4	1	0.71	0.5	0.35	0.25	0.18	0.13	0.09	0.06	D50 (mm)	D84 (mm)	D16 (mm)
26/04/2014	LP 1,2	18.6	100	100	100	100	100	100	100	100	100	100	99	92	59	17	3	0	0	0	0	0	0.66	0.92	0.49
26/04/2014	LP 3	137.8	100	100	100	100	100	100	100	100	100	100	99	98	87	58	21	1	0	0	0	0	0.46	0.69	0.32
26/04/2014	LP 4	135.3	100	100	100	97	96	96	95	95	95	94	91	84	69	40	7	0	0	0	0	0	0.56	0.99	0.39
26/04/2014	LP 5	18.3	100	100	100	100	91	91	88	86	85	83	80	76	68	46	16	2	0	0	0	0	0.53	2.43	0.35
26/04/2014	LP 6	9.2	100	100	100	100	100	94	91	86	84	83	83	79	73	58	27	6	1	0	0	0	0.46	2.89	0.30
26/04/2014	LP 7	20.7	100	100	100	100	95	87	79	75	68	61	56	50	43	36	23	9	1	0	0	0	1.03	6.93	0.30
26/04/2014	LP 8	22.5	100	100	100	100	100	97	94	91	84	76	67	56	47	39	28	9	1	0	0	0	0.80	2.81	0.29
26/04/2014	LP 9	24.8	100	100	100	100	100	96	96	94	92	88	82	67	51	37	25	7	0	0	0	0	0.70	1.59	0.30
26/04/2014	LP 10	27.5	100	100	100	100	86	80	77	76	75	75	74	72	67	57	34	6	1	0	0	0	0.45	9.15	0.28
26/04/2014	LP 11	7.5	100	100	100	100	100	100	95	93	93	92	91	90	86	78	52	10	1	0	0	0	0.35	0.64	0.26
26/04/2014	US 2	3.5	100	100	100	100	100	100	100	100	100	100	98	95	91	82	53	15	5	3	1	1	0.34	0.53	0.25
26/04/2014	US 3	13.3	100	100	100	100	100	100	100	100	100	100	100	99	98	88	49	6	1	0	0	0	0.36	0.48	0.27
26/04/2014	US 4	62.3	100	100	14	14	8	8	7	7	6	6	5	5	4	3	2	0	0	0	0	0	25.97	29.93	22.53
26/04/2014	US 5	10.9	100	100	100	100	100	100	100	98	97	92	84	71	53	34	15	3	0	0	0	0	0.67	1.41	0.36
26/04/2014	US 6	1.9	100	100	100	100	100	100	100	100	96	96	96	92	83	65	34	6	0	0	0	0	0.43	0.75	0.28
27/05/2014	LP 2,3	42.2	100	100	100	100	100	100	100	100	100	100	99	97	86	47	13	1	0	0	0	0	0.51	0.70	0.37
27/05/2014	LP 4	267.1	100	100	96	93	89	87	85	83	80	77	71	63	50	34	13	2	0	0	0	0	0.71	4.75	0.37
27/05/2014	LP 5	29.6	100	100	100	100	55	31	23	20	19	17	17	16	15	13	7	1	0	0	0	0	10.46	14.10	0.86
27/05/2014	LP 6	24.8	100	100	100	77	72	61	58	53	46	41	36	31	26	18	9	6	1	0	0	0	3.42	17.71	0.46
27/05/2014	LP 7	8.4	100	100	100	100	85	72	70	68	62	55	48	39	31	23	13	5	1	0	0	0	1.58	10.80	0.39
27/05/2014	LP 8,9	185.3	100	100	65	58	45	40	38	37	35	34	32	30	24	17	10	2	0	0	0	0	12.93	27.09	0.48
27/05/2014	LP 10	50.8	100	100	100	86	58	51	46	44	43	42	41	40	37	32	19	3	0	0	0	0	7.29	15.61	0.33
27/05/2014	LP 11	6.1	100	100	100	100	100	100	100	100	99	99	98	97	94	85	56	12	4	2	1	1	0.34	0.49	0.26
27/05/2014	LP 12	46.7	100	100	100	94	80	70	65	59	56	53	51	50	47	41	24	6	1	0	0	0	1.03	12.44	0.30
27/05/2014	US 2	9.0	100	100	100	100	100	100	100	100	100	100	99	99	96	83	38	5	0	0	0	0	0.39	0.52	0.28
27/05/2014	US 4	47.9	100	100	100	100	100	100	99	99	99	97	92	86	72	48	19	2	1	0	0	0	0.52	0.95	0.33
27/05/2014	US 6,8	3.0	100	100	100	100	100	100	100	100	99	97	96	91	80	62	36	7	1	0	0	0	0.43	0.81	0.28
28/05/2014	LP 1,2	1.1	100	100	100	100	100	100	100	100	98	96	86	77	61	53	37	21	10	1	0	0	0.47	1.31	0.21
28/05/2014	LP 3	35.6	100	100	100	100	100	100	100	100	100	100	100	99	95	84	44	6	0	0	0	0	0.37	0.50	0.27
28/05/2014	LP 4	21.5	100	100	100	100	87	82	72	64	61	53	47	40	31	20	10	2	0	0	0	0	1.69	8.73	0.44
28/05/2014	LP 5	121.4	100	100	100	100	100	100	99	98	96	94	89	82	69	48	20	3	0	0	0	0	0.52	1.08	0.33
28/05/2014	LP 6	14.0	100	100	100	61	47	30	27	26	24	23	21	19	16	11	6	2	0	0	0	0	12.02	19.43	0.70
28/05/2014	LP 7	45.1	100	100	100	45	23	14	11	10	10	9	8	7	5	4	2	1	0	0	0	0	16.52	20.26	8.29
28/05/2014	LP-8	7.3	100	100	100	100	100	100	96	89	78	69	60	50	40	33	27	11	2	1	0	0	1.00	3.43	0.28
28/05/2014	LP-9	24.9	100	100	100	100	96	92	92	92	91	90	87	83	71	54	35	9	1	1	0	0	0.47	1.09	0.27
28/05/2014	LP-10	37.8	100	100	100	89	89	89	88	87	86	85	85	84	80	67	37	6	0	0	0	0	0.41	1.10	0.28
28/05/2014	LP 11	15.1	100	100	100	100	90	85	77	74	70	67	63	60	54	43	26	5	1	0	0	0	0.62	7.79	0.30
28/05/2014	LP-12	10.0	100	100	100	100	100	100	95	95	93	91	89	87	83	71	42	13	2	1	0	0	0.39	0.78	0.26
28/05/2014	US 2	8.6	100	100	100	100	100	100	100	100	100	99	99	98	97	92	57	8	1	0	0	0	0.34	0.46	0.26
28/05/2014	US-3	19.4	100	100	100	100	100	100	100	100	100	100	99	97	85	62	22	2	0	0	0	0	0.45	0.70	0.32
28/05/2014	US 4,5	9.0	100	100	100	100	100	100	99	98	95	89	80	70	56	41	27	5	0	0	0	0	0.61	1.65	0.30
28/05/2014	US 6	3.6	100	100	100	100	100	72	72	69	68	64	56	48	38	27	15	4	0	0	0	0	1.08	9.95	0.37
28/05/2014	US 7	9.4	100	100	100	100	100	100	99	96	88	73	51	35	20	12	7	2	1	0	0	0	1.37	2.57	0.59
28/05/2014	US 8,9	0.3	100	100	100	100	100	100	100	100	86	86	71	57	29	14	0	0	0	0	0	0	0.92	1.92	0.52
10/07/2014	LP 2-5	46.9	100	100	100	91	88	85	80	76	73	69	64	59	52	39	18	4	0	0	0	0	0.68	7.64	0.34
10/07/2014	US 2-8	6.2	100	100	100	100	100	100	100	100	100	100	98	95	87	70	39	8	1	0	0	0	0.40	0.67	0.27
15/07/2014	LP2-10	115.0	100	100	100	88	62	53	48	45	43	40	39	36	33	29	19	7	1	0	0	0	6.44	15.16	0.32
15/07/2014	US 2-7	6.6	100	100	100	100	100	100	100	100	100	100	99	97	93	76	33	9	3	2	1	1	0.41	0.59	0.28
18/07/2014	LP2-10	81.6	100	100	100	91	79	76	73	71	69	67	65	63	58	52	35	12	2	1	0	0	0.48	12.85	0.27
18/07/2014	US1-8	49.5	100	100	100	100	100	100	98	97	95	93	89	84	76	61	30	7	2	1	0	0	0.44	1.00	0.29
21/07/2014	LP2-12	237.0	100	100	100	98	93	91	88	87	86	85	84	83	80	74	51	14	1	0	0	0	0.35	1.29	0.25
21/07/2014	US1-9	372.6	100	100	98	98	97	97	96	95	94	92	90	88	85	74	30	4	0	0	0	0	0.41	0.68	0.29
23/07/2014	LP 1-12	218.9	100	100	100	97	95	94	93	92	91	90	89	87	83	72	40	7	0	0	0	0	0.39	0.79	0.28
23/07/2014	US 1-9	103.9	100	100	100	100	100	100	99	98	98	97	96	93	86	70	31	4	0	0	0	0	0.42	0.67	0.29
24/07/2014	LP 1-11	585.2	100	100	93	79	57	44	35	30	27	24	22	21	18	15	9	2	0	0	0	0	9.41	18.16	0.57
24/07/2014	US 1-8	142.3	100	100	100	100	100	100	100	100	99	99	98	96	88	68	25	3	0	0	0	0	0.43	0.66	0.31
13/08/2014	LP 1-12	156.8	100	100	100	100	98	96	95	94	92	91	90	89	86	78	47	8	1	0	0	0	0.37	0.66	0.27
13/08/2014	US 1-9	536.2	100	100	96	96	95	94	94	93	92	91	88	84	76	62	29	4	0	0	0	0	0.44	1.03	0.30

Appendix D Suspended Sediment Transport Data

Time	Position (m)	Mass (mg)					Volume	Concentration
		500 sed	250 sed	125 sed	64 sed	< fine sed	(L)	(mg/L)
				12-Oct-13				
12:44	**weighted sum**	-	-	-	-	-	-	**3.12**
				25-Apr-14				
10:03	30	0.10	0.20	0.80	0.20	19.70	0.56	37.42
10:22	35	0.00	0.00	0.20	0.70	15.50	0.66	25.03
10:32	40	0.00	0.40	0.70	0.60	15.90	0.71	24.84
10:37	45	0.00	0.10	0.40	0.30	7.20	0.39	20.59
10:47	60	0.30	3.20	2.10	0.10	11.90	0.74	23.80
11:00	55	0.60	2.10	1.40	0.50	14.60	0.75	25.51
11:15	60	0.50	0.90	1.50	0.30	17.20	0.77	26.63
12:35	65	0.10	0.40	2.10	1.10	11.60	0.67	22.78
11:43	70	0.00	1.00	1.10	0.10	9.50	0.56	20.83
11:50	75	0.00	0.40	0.80	0.50	9.50	0.55	20.30
11:57	80	0.00	0.30	0.20	0.00	8.70	0.49	18.88
12:03	85	0.20	0.50	1.20	0.40	5.90	0.33	24.94
12:15	90	0.00	0.30	1.40	0.20	9.50	0.60	19.07
12:22	95	0.00	0.40	0.90	0.00	9.60	0.59	18.43
12:27	100	0.00	0.60	1.60	0.10	13.00	0.74	20.79
12:31	105	0.00	0.00	1.50	0.60	9.90	0.63	19.03
12:35	110	0.00	1.40	0.50	0.60	11.80	0.70	20.51
12:40	115	0.00	0.00	0.20	0.10	7.30	0.44	17.15
12:48	120+125+130+135	0.00	0.00	0.20	0.00	4.20	0.29	15.14
11:07	**weighted sum**	**0.08**	**0.55**	**0.88**	**0.29**	**10.23**	**0.55**	**22.02**
				25-Apr-14				
17:00	30	0.70	0.40	1.00	0.30	15.10	0.37	47.42
17:05	40	1.30	0.60	2.00	1.80	9.20	0.64	23.27
17:10	50	1.30	1.40	2.70	1.50	11.80	0.69	27.23
17:13	60	0.10	1.90	1.20	0.00	13.30	0.74	22.33
17:16	70	0.40	0.70	1.80	1.30	9.50	0.71	19.38
17:20	80	0.20	0.70	1.10	0.20	9.10	0.52	21.55
17:25	90	0.10	0.50	1.40	0.60	10.80	0.64	21.01
17:29	100	0.40	0.30	1.90	0.60	13.20	0.72	22.77
17:31	110	0.00	0.80	0.70	0.20	9.70	0.63	18.17
17:34	120+130	0.00	0.20	0.00	0.20	3.20	0.20	17.60
17:18	**weighted sum**	**0.41**	**0.70**	**1.25**	**0.63**	**9.83**	**0.55**	**23.27**
				28-May-14				
10:01	35	0.00	0.70	0.00	0.00	0.00	0.64	1.09
10:20	55	1.00	2.10	0.00	0.00	0.00	0.89	3.50
10:30	65	1.10	2.60	1.00	0.00	6.20	0.86	12.71
10:36	75	0.00	0.40	0.80	0.70	7.80	0.86	11.22
10:44	80	0.30	0.40	0.50	0.20	4.50	0.70	8.49
10:50	90	0.00	0.30	0.20	0.70	5.30	0.88	7.36
10:55	100	0.00	0.30	2.20	0.00	7.40	0.90	11.02
11:01	110	0.00	0.30	0.00	0.00	5.90	0.87	7.13
11:17	115	0.30	2.30	1.30	0.50	6.20	0.79	13.41
11:24	130	0.00	0.60	0.00	0.00	0.00	0.39	1.55
10:45	**weighted sum**	**0.30**	**1.07**	**0.54**	**0.18**	**3.69**	**0.76**	**7.57**