Nechako River 2013 Sediment Transport Investigations

BRITISH COLUMBIA

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EXECUTIVE SUMMARY

The development of the Kemano Project in the early 1950's has 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 a series of investigations to assess the historical and contemporary characteristics of the reach.

As part of this ongoing sturgeon recovery effort for the Nechako River, Northwest Hydraulic Consultants Ltd. (NHC) completed two field trips to the Vanderhoof Reach to assess bedload sediment transport during high and low flow conditions for the Ministry of Forests, Lands and Natural Resource Operations. Four study sites were selected and at each site a transect was established across the channel with several sampling stations spaced across the channel. At each station a bedload sample was collected, a vertical velocity profile was measured and an underwater camera was deployed.

The bedload transport sampling investigations demonstrated that fine gravel and coarse sand is mobile at relatively low flows in the Vanderhoof Reach. The discharge and shear stress data, coupled with the observed transport rates shows that transport rates are not directly related to flow and shear, but within channel storage and local reworking of stored sediment is also factor. The observations suggest that if the hydraulics and sediment transport patterns are appropriate, placed substrate may remain relatively clear of fines for a number of years.

The initial sediment budget analysis suggests that the timing of sediment transport at the different sites varies, and it remains unclear when bedload is transported into the Vanderhoof Reach. On account of these observations, it is recommended that more bedload sampling at different flows and different times of the year be conducted at the Upper Site and Lower Patch.

Summary of the sediment transport for the Vanderhoof Reach of the Nechako.

		Fort Fraser	Upper Site	Middle Patch	Lower Patch	Lower Site
August	Qs (g/s)	**6235**	**186**	**245**	**5793**	**2308**
	Q (m^3/s)	270	331	92	321	316
	Avg. shear stress (Pa)	3.48	27.09	2.37	5.58	4.47
October	Qs (g/s)	Not Applicable	**1**	**97**	**4**	**319**
	Q (m^3/s)	Not Applicable	48	30	48	45
	Avg. shear stress (Pa)	Not Applicable	4.25	5.85	5.47	4.77

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NOTIFICATION

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CERTIFICATION

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- Zsolt Sary

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1 INTRODUCTION

In May 2011 the Ministry of Forest, Lands and Natural Resource Operations placed substrate in two locations in the Nechako River at Vanderhoof, BC to improve the availability of clean coarse gravel-cobble substrate that White Sturgeon can use to spawn. The substrate is intended to provide interstitial spaces that sturgeon eggs can fall between and larvae can hide in, thereby reducing predation (McAdam et al., 2005). If the interstitial spaces become filled with fine sediment the effectiveness of the substrate is reduced.

In 2011 and 2012 substrate assessments were completed to assess the condition of the placed substrate (NHC, 2012, 2013a). During these assessments it was observed 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. It was also observed in 2012 that coarse sand was mobile at the Burrard Street Bridge despite relatively low flows. These observations, and other information was subsequently compiled and reviewed as part of a Geomorphology Charette held on February 28th, 2013 in Vancouver BC. An outcome of the Charette was the identification of a series of important research questions to guide future studies (NHC, 2013b).

This report and the associated field studies are intended to partially address some of these research questions. In particular:

1. The pattern of sediment transport past the placed substrate was investigated to determine if sediment was overpassing and being flushed out of the interstitial spaces, or if the areas that were remaining clear were not exposed to the mobile bedload.
2. Methods of measuring and assessing sediment transport through the Vanderhoof reach were evaluated and a first order assessment of sediment transport rates at a low and high flow were completed.

During the October, 2013 fieldwork underwater images were also used to assess the substrate condition at the two patches **(Figure 1)**. The work was completed with support from Ministry of Forests, Lands and Natural Resource Operations personnel. Boat and driver support was supplied by John Summers.

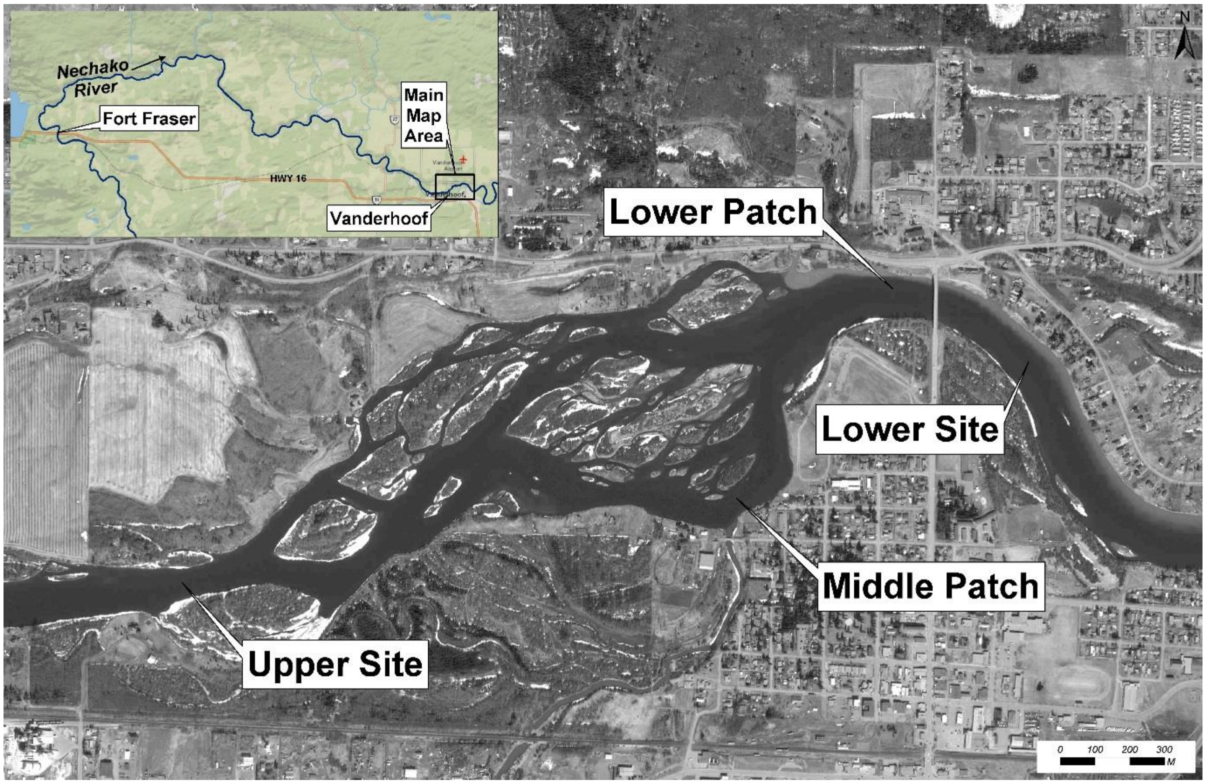

Figure 1: Overview map illustrating sampling locations on the Nechako River. Substrate was placed in 2011 at the middle and lower patch. Other sites are composed of native substrate.

1.1 BACKGROUND

Development of the Kemano Project in the early 1950's altered the flow regime throughout the Nechako River. Past studies (NHC, 2009, 2006, e.g. 2002) 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 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. 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 is particularly relevant). These investigations have revealed the following (as summarized in NHC, 2012):

- The spawning reach occurs at a distinct reduction in channel gradient (0.06 % upstream to 0.03 % downstream (NHC, 2006)).
- The substrate at the top of the reach is cobble-gravel while the substrate at the downstream end of the reach is gravel-sand.
- 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).
- The Cheslatta fan avulsions that occurred between the late 1950's and 1972 introduced 0.86 to 1.1 million cubic meters 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 **(Figure 2)** 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.

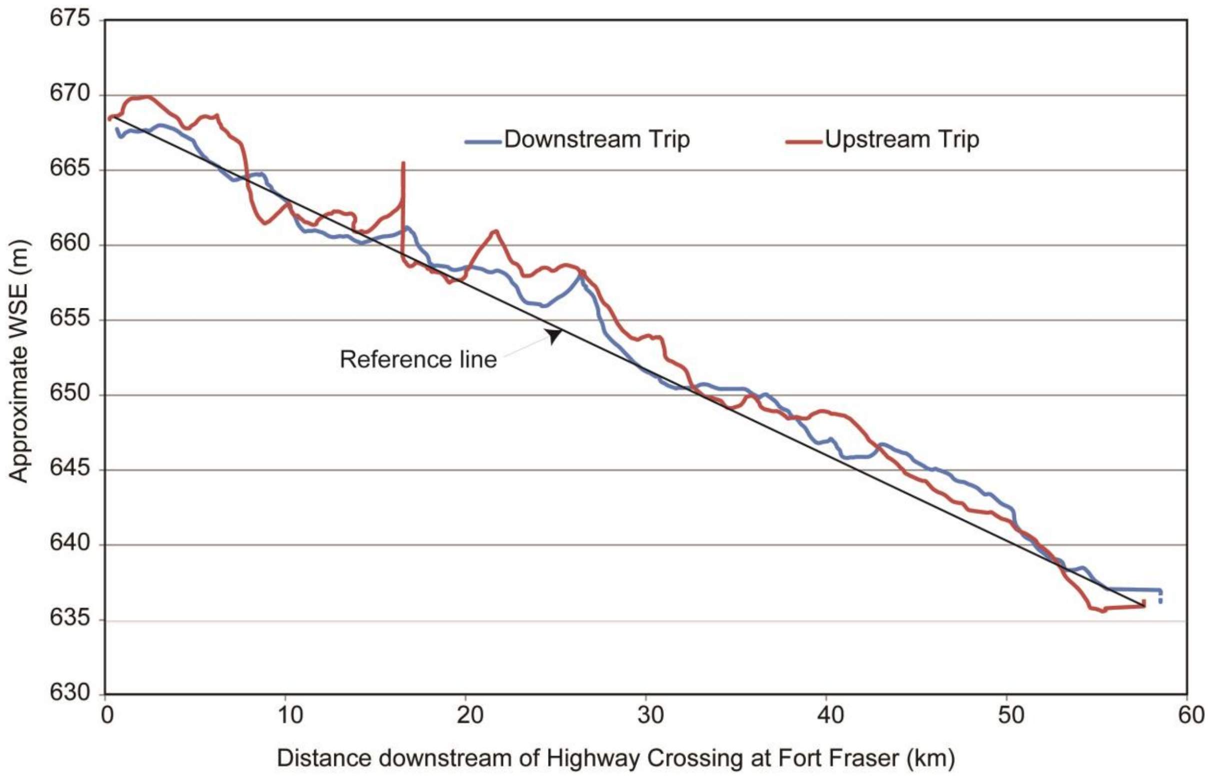

Figure 2: Approximate long profile of Nechako River from Highway Crossing at Fort Fraser to Lower Site downstream of Burrard Street Bridge in Vanderhoof. Upper site is located at the 56 km point.

1.2 STUDY RATIONALE AND APPROACH

This report and the associated field studies are intended to partially address two research questions.

1. What is the pattern of sediment transport past the placed substrate?
2. What are appropriate methods for measuring sediment transport in the Vanderhoof Reach?

The primary field investigation was completed in August 2013 during relatively high flow conditions (Q= 325 m^3/s; exceeded 8.8 % of the time). A more limited set of investigations was completed in October 2013 during low flow conditions (48 m^3/s). During the October, 2013 fieldwork underwater images were also used to assess the substrate condition at the two patches **(Figure 1)**.

During both trips a measurement of the bedload transport rate was conducted at four locations within the Vanderhoof Reach. During the August trip an additional measurement was also collected upstream of the highway crossing at Fort Fraser. This measurement provided an assessment of upstream supply and also enabled an assessment of river morphology between Vanderhoof and Fort Fraser. 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).**

Table 1: Wentworth grain size scale.

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

2 SITE DESCRIPTION AND OVERVIEW OF RIVER MORPHOLOGY FROM FORT FRASER TO VANDERHOOF

In May of 2011 substrate was placed in two pools just upstream of the Burrard Avenue Bridge in Vanderhoof, BC. These two locations are referred to herein as the Middle Patch and Lower Patch. During the 2012 substrate assessment, a site upstream of the placed material and a site downstream of the placed material were also sampled. Many eggs were collected at the Lower site during the spring of 2012, while the upper site was historically used as a spawning site by sturgeon. The location of all the sites is shown in **Figure 1**.

As part of the August field visit the Nechako River was assessed via a jet boat from Vanderhoof to Fort Fraser. During this assessment a better perspective of channel morphology was attained and a more detailed assessment of the river using the photos and observations from the field assessment is now possible. Geo-referenced field photos collected during the field work are temporarily available at:
http://share.nhcweb.com/public.php?service=files&t=6e6d230c8a94ff858be9f920a91dab75

3 METHODS

In part the purpose of the 2013 study was to try a number of different approaches of assessing sediment transport in the Nechako River at Vanderhoof. The follow sections describe each method and their benefits/challenges and things that could be improved.

3.1 HELLYSMITH SAMPLING

A Helleysmith sampler 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. If transport rates were exceptionally high and the bag became full, or nearly full additional samples were collected for shorter duration periods. During the October low flow measurements most samples were collected over a 10 minute period.

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. Samples where individually labelled and sieved at the UBC Geography Department using ½ phi sieves.

The Hellysmith sampler was relatively easy to use and provided reasonably accurate information about the mobility of the sediment at the sites. The biggest challenge was holding the boat still, especially at the Upper Site where velocities where faster. During subsequent field work a large anchor coupled with a windlass winch would greatly facility sampling.

Figure 3: Photo showing the Hellysmith sampler and crane mount that were used.

3.2 ADCP Moving Bottom Observations

A RDI Acoustic Doppler Current Profiler (ADCP) **(Figure 4)** was used to monitor if the bed was observed to be moving at each of the sites as well as the mean velocity profile when the samples were being collected. Before or after collecting each set of HellySmith samples the discharge through the channel was also measured. A Real Time Kinetic (RTK) GPS was mounted on the ADCP boat during the August sampling to enable flow measurements during moving bottom conditions.

While the Hellysmith samples were being collected, the ADCP was also used to determine if a moving bottom was detected at the sampling site, and the near bed shear stress. During most of the tests between 2 and 4 minutes of velocity data were collected. The velocity at the bottom was determined by dividing the apparent distance moved by the sampling duration. The lower portion of the velocity profile was used to estimate near bed shear stress **(Figure 5)**.

The ADCP helped confirm the shear stress and velocity pattern at the sites and detected a moving bottom at a few of the sampling sites during the August field trip. While the ADCP does provide additional information about the flow characteristics and confirms the WSC discharge data, it is not critical for additional sampling work that may be undertaken.

Figure 4: **GPS mounted above ADCP that was used to determine velocity and moving bottom conditions.**

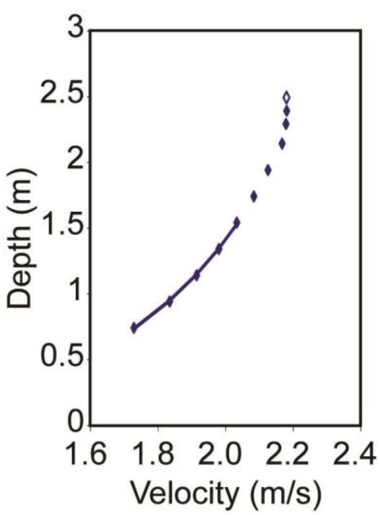

Figure 5: **Example velocity profile used to determine near bed shear stress.**

3.3 Underwater Camera Observations of Sediment Transport

Underwater images of the substrate were collected with NHC's Video-GPS data acquisition system. The system collects GPS data from a handheld GPS and still images from a SeaViewer Underwater Camera. A weighted tripod mount allows the camera to be positioned in a stable viewpoint over the bed.

During both the August and October sampling trips the camera was deployed along with the HelleySmith sampler to allow for direct observation of the bedload transport conditions. This provided a valuable confirmation that the samples we were collecting were representative of the transport at each sample site.

3.4 P61 Sampling

Samples of the sediment in suspension in the water column were collected with a 100 lb. (45 kg) P-61 point integrating sediment sampler. The P-61 nozzle has an inside diameter of 4.76 mm and can accurately collect sediment with a grain diameter of up to about 1 or 2 mm without bias. Above this size there is an increased risk that the grains will make contact with the rim of the nozzle and be bounced out of the sampler. The P-61 is an isokinetic sampler which means that the sampling nozzle allows water to enter the bottle at the same velocity as the ambient water velocity in the channel. This provides a set of samples which are representative of the concentration of suspended sediment in the channel during the sampling period.

In conjunction with the crane, the P-61 was relatively easy to deploy and the solenoid valve allows for straightforward control of the sampling duration. During testing, the sampler was carefully lowered to the bottom as to not disturb the bed material, the nozzle was opened for a 30 second duration, closed and then returned to the surface. Test samples with the P-61 captured very little suspended sediment. The water was clear with the exception of a few sand grains which quickly settled to the bottom of the sample container **(Figure 6)**. This supported the hypothesis that most of the sediment in transport was moving as bedload, near or in contact with the bed rather than through the water column. On account of the success of the Hellysmith sampling and the small amount of sediment collected with the P61 sampler, the P61 was not used in any systematic way and not recommended for additional sampling trips.

Figure 6: Water Sample from Nechako River Collected in August 2013. Sand grains are clearly visible in otherwise clear water.

3.5 UNDERWATER CAMERA OBSERVATIONS OF PATCH CONDITION

In addition to observing sediment transport, the Seaviewer Underwater Camera was used for conducting an assessment of the patch substrate and the Middle and Lower sites. The assessment was conducted on October 11th, 2013 during a discharge of $49m^3/s$ which limited the areas that were accessible by boat. Longitudinal transects of the patches were completed with photos of the bed collected every couple of meters. Each image was reviewed on screen and the substrate was classified as one of the following substrate types:

- Sand
- Gravel with less than 10 % sand
- Gravel with 10-20 % sand
- Gravel with 20-40 % sand
- Gravel with 40-70 % sand
- Cobble with less than 10 % sand
- Cobble with 10-20 % sand
- Cobble with 20-40 % sand
- Cobble with 40-70 % sand

Any substrate type with more than 70 % sand was classified as sand. The classification scheme was developed to emphasis the difference between areas with little to no sand (less than 10 %), some sand (10-20%) and sufficient sand that functional interstitial spaces are unlikely to exist (20-40 and 40-70%); hence the classes are not uniform.

To help develop a manual classification process, the sand covered portion of a series of photos was digitized and compared to the total area of the image that was composed of river bed. This yielded a direct measure of the percent of the bed covered by sand. These training images and the percent sand associated with each image can be found in the 2012 Substrate Assessment (NHC, 2013a). The training images were used as a guide to classify all of the underwater images using the 9 classes noted above. The location of each of the underwater images was subsequently plotted in GIS and color coded using the substrate type. These data are shown in **Map 1** and **Map 2**.

With respect to biological function, a cobble substrate with no 'clean substrate' indicates that sand fills the interstitial spaces and there are no open pore spaces. This does not however mean that there is no micro-topography and flow refugia behind the cobbles that can provide some habitat value. To assess if any habitat value exists when the interstitial spaces are filled the percent of the bed covered by sand can be used. Generally speaking sites with more than 40 % sand provide poor habitat, sites with 20-40 % sand provide fair habitat at best, sites with 10-20 % sand provide fair to good habitat, while sites with less than 10 % sand likely provide good habitat. Excellent habitat can only be assessed with the freeze cores and is only appropriate in sites with less than 10 % sand. It is hypothesized that in general sites with the same percent sand, that are predominantly cobble, rather than gravel, will provide better habitat as they will have larger interstitial spaces and create greater hydraulic roughness.

4 Observations

4.1 Sediment Transport

Two rounds of sediment sampling were conducted. The first occurred from August 15-16, 2013 and the second on October 11-12, 2013. The August trip was during the cold water release from the Kenney Dam and represented the higher end of flow experienced annually (~320m³/s). The October trip was representative of the lowest discharge expected during ice free conditions (~48m³/s). At each site a transect was established across the channel and several stations were sampled at even intervals across the channel. At each station a sediment sample was collected, a vertical velocity profile was measured and the underwater camera was deployed. A summary of the results is given in **Table 2** and the results for each site are presented in the following section. Complete results are provided in **Appendix A**.

Table 2: Summary of the two sampling trips.

		Fort Fraser	Upper Site	Middle Patch	Lower Patch	Lower Site
August	Qs (g/s)	**6235**	**186**	**245**	**5793**	**2308**
	Q (m^3/s)	270	331	92	321	316
	Avg. shear stress (Pa)	3.48	27.09	2.37	5.58	4.47
October	Qs (g/s)	Not Applicable	**1**	**97**	**4**	**319**
	Q (m^3/s)	Not Applicable	48	30	48	45
	Avg. shear stress (Pa)	Not Applicable	4.25	5.85	5.47	4.77

4.1.1 Complications

One of the requirements of taking a representative sample is making sure that the boat is securely anchored and is stationary for the duration of the measurement. For most of the sites this was not an issue, however along the thalweg and at a two of the sites, the river velocity was sufficient to cause the boat to drag the anchor. If boat movement potentially caused the HelleySmith to dredge along the bottom, the sample was rejected and an additional sample was collected. During the sampling, the tension on the cable was monitored to make sure the cable remained slack. Small amounts of boat drift where accommodated by slowly letting cable out so that the cable remained slack.

In sampling locations with high transport rates, the movement of sand sheets along the bed prevented the ADCP from getting an accurate lock on the bed, which affected the calculated velocity profile. The software assumes the bed is stationary, so a measurement taken with a stationary boat appears to be slowly moving upstream. To overcome this problem, an RTK GPS was used that was able to feed real-time position into the ADCP software via Bluetooth. This allowed the velocity data to be corrected as well as provide an estimate of the average speed of the bedload.

4.1.2 Upper Site

The upper site is characterized by a fairly straight channel and fairly uniform cross section. This site was added to the study to help determine the amount of sediment coming into the patches from further upstream. A sampling transect was established that runs roughly through the middle of the site **(Figure 7)**. The bed material at this site is primarily cobble with sand and gravel mixed into the interstices.

During the August sampling trip moderate transport rates were found along the left bank with a decrease trend across the channel despite high shear stress across the entire channel **(Table 3)**. The maximum transport rate found at US-A, the site closest to the left bank, at 6.1 g/m/s **(Photo 1)**. Sampling at the Upper Site proved to be the most challenging of all the sites as the high velocities and cobble bed prevented the boat from anchoring securely.

During the October sampling trip no sediment was captured at any of the stations **(Photo 2)**. An additional two stations were added compared to the August trip to ensure that the sampling spatial density was high enough and any discrete areas of transport were not missed.

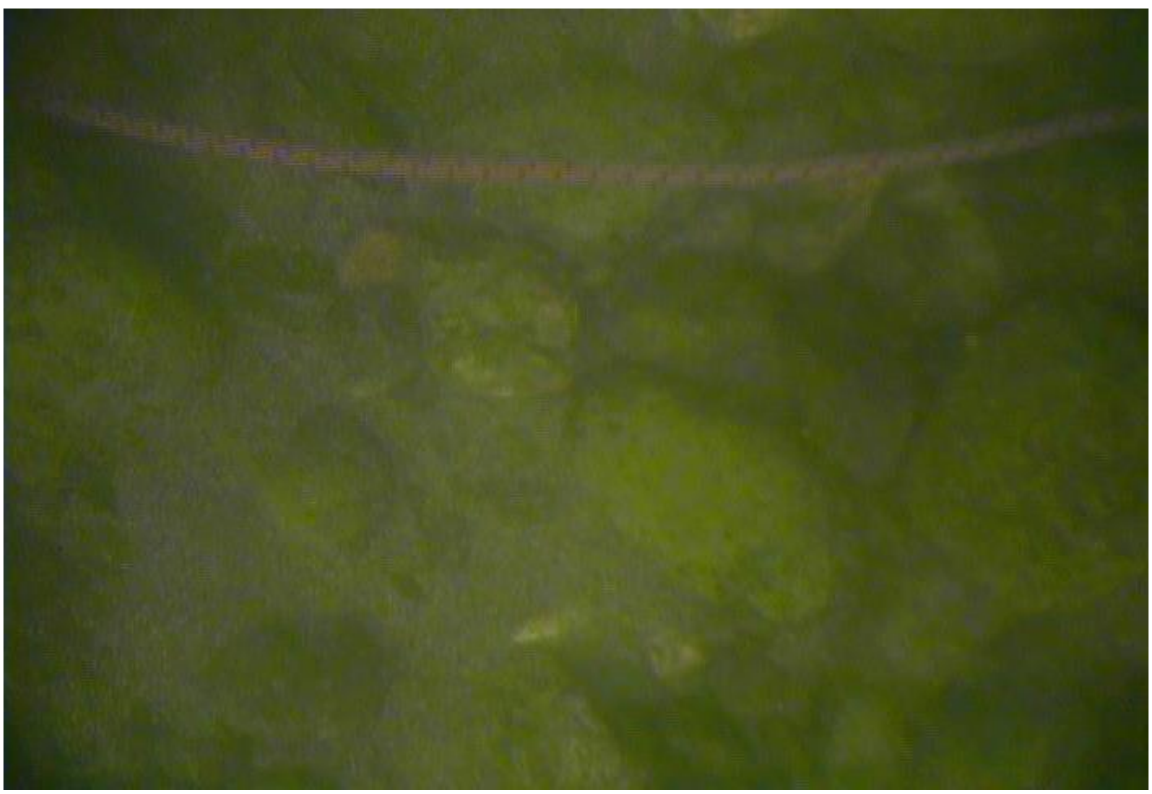

Photo 1: Bed material at US-A during the August trip.

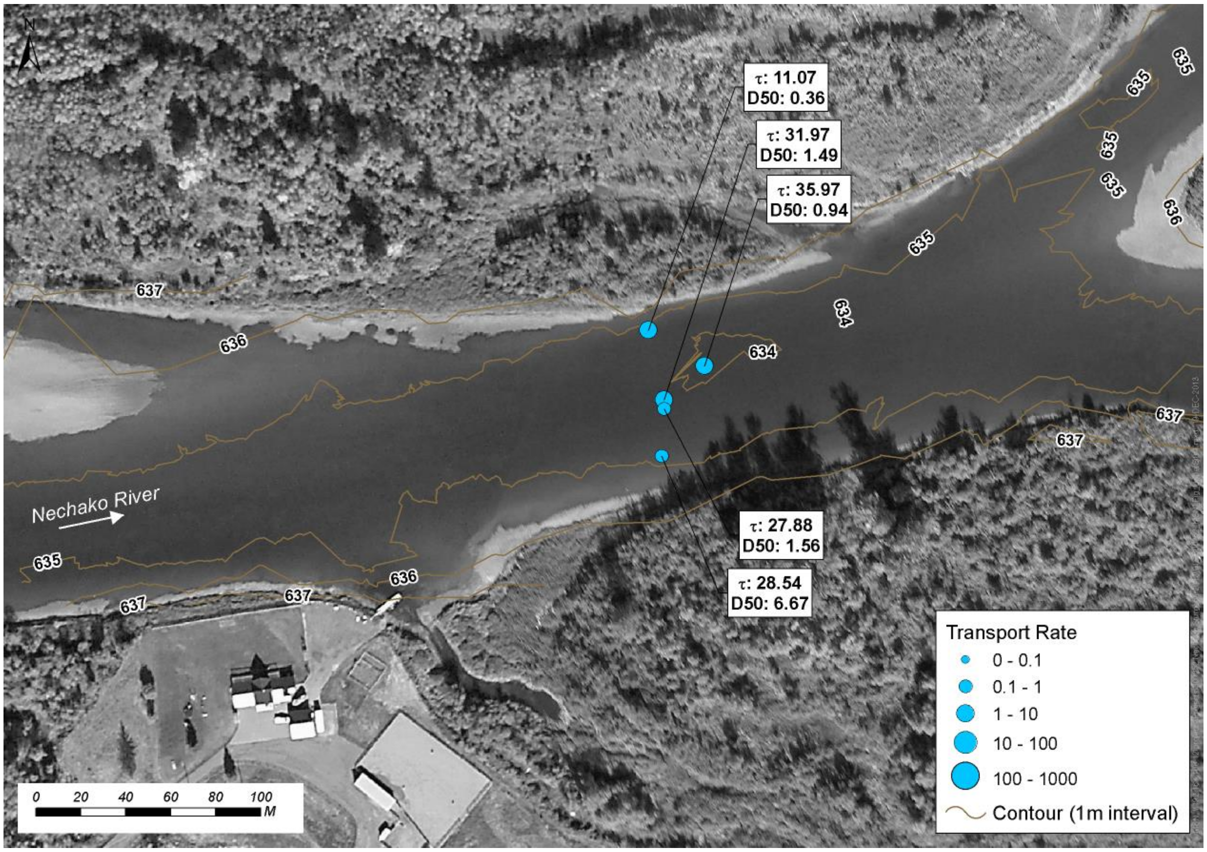

Figure 7: **Overview of the August sampling sites for the Upper Site. Shear stress (Pa) and D_{50} (mm) are given for each station. Transport rate (g/m/s) is represented by the size of the circle.**

Photo 2: **US-C during the October sampling trip.**

Table 3: **Summary of the Upper Site sampling**

Date	Site	US-A	US-B	US-C	US-D	US-E	US-F	US-G
August	Mean Velocity (m/s)	1.54	1.99	2.04	2.04	1.80	-	-
	Depth (m)	2.04	2.83	2.80	2.84	2.09	-	-
	Near Bed Shear Stress (Pa)	11.07	35.97	31.97	27.88	28.54	-	-
	Transport Rate (g/s/m)	6.1	5.2	0.8	0.6	1.1	-	-
October	Mean Velocity (m/s)	0.33	0.44	0.57	0.67	0.77	0.75	0.56
	Depth (m)	0.59	0.76	0.92	1.07	1.01	1.10	0.98
	Near Bed Shear Stress (Pa)	1.98	2.28	5.61	3.87	8.24	6.25	1.54
	Transport Rate (g/s/m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.1.3 MIDDLE PATCH

The middle patch is located in the right most channel of a braided island complex extending downstream from the confluence of Stony Creek along the right bank. The channel is deeper at the upstream end of the patch and along the right bank which is covered in improvised riprap consisting of concrete rubble. The channel depth decreases considerably towards the left bank, which is a well vegetated island and in the downstream direction. A sampling transect was established that roughly bisects the middle of the patch **(Figure 8)**.

During the August sampling trip the two stations closest to the right bank (Stations MP-A and MP-B) did not return any sediment. The bed along this side of the channel is composed of placed coarse cobble and occasional gravel **(Photo 3)**. The lack of sediment in transport along this section of channel is consistent with observations from 2012 that showed that the lack of sediment transport had allowed for thick filamentous algae growth on the coarse substrate (NHC, 2013a).

The middle station (MP-C) returned the largest amount of sediment along this section and had a calculated transport rate of 10.2 g/m/s **(Photo 4)**. This station was located along the edge of a lateral bar that extends out from the island on the left bank. The bar material is primarily gravel but has a large sand component and visible strips of sand are visible along the surface. The higher transport rate is partially due to sand avalanches along the leading edge of this bar. Samples MP-D and MP-E are located on this bar surface and returned lower transport rates (3.1 and 0.2 g/m/s, respectively.) These stations are in line with the main flow between the islands upstream of the site.

During the October sampling trip, low water levels made access to this site difficult and station MP-E could not be access by boat. The first three station samples did not return any sediment. Station MP-D, however, had a calculated transport rate of 5.4 g/m/s. This was likely material being mobilize locally along the lateral bar. As in the August sampling trip, there were no signs of sediment transport through the placed coarse cobble substrate along the right bank which was primarily free of sand and had thick algae mats. A summary of all the sampling is provided in **Table 4**. On both trips, the highest shear stress is found at the station with the highest transport rate at this site.

Table 4: Summary of the Middle Patch sampling.

Date	Site	MP-A	MP-B	MP-C	MP-D	MP-E
August	Mean Velocity (m/s)	0.43	0.60	0.67	0.58	0.58
	Depth (m)	2.62	3.10	2.07	2.04	1.79
	Near Bed Shear Stress (Pa)	3.28	0.69	6.24	1.00	0.64
	Transport Rate (g/s/m)	0.0	0.0	10.2	3.1	0.2
October	Mean Velocity (m/s)	1.05	1.10	0.90	0.58	-
	Depth (m)	2.53	1.51	1.43	0.85	-
	Near Bed Shear Stress (Pa)	3.06	7.15	12.83	0.37	-
	Transport Rate (g/s/m)	0.0	0.0	5.4	0.0	-

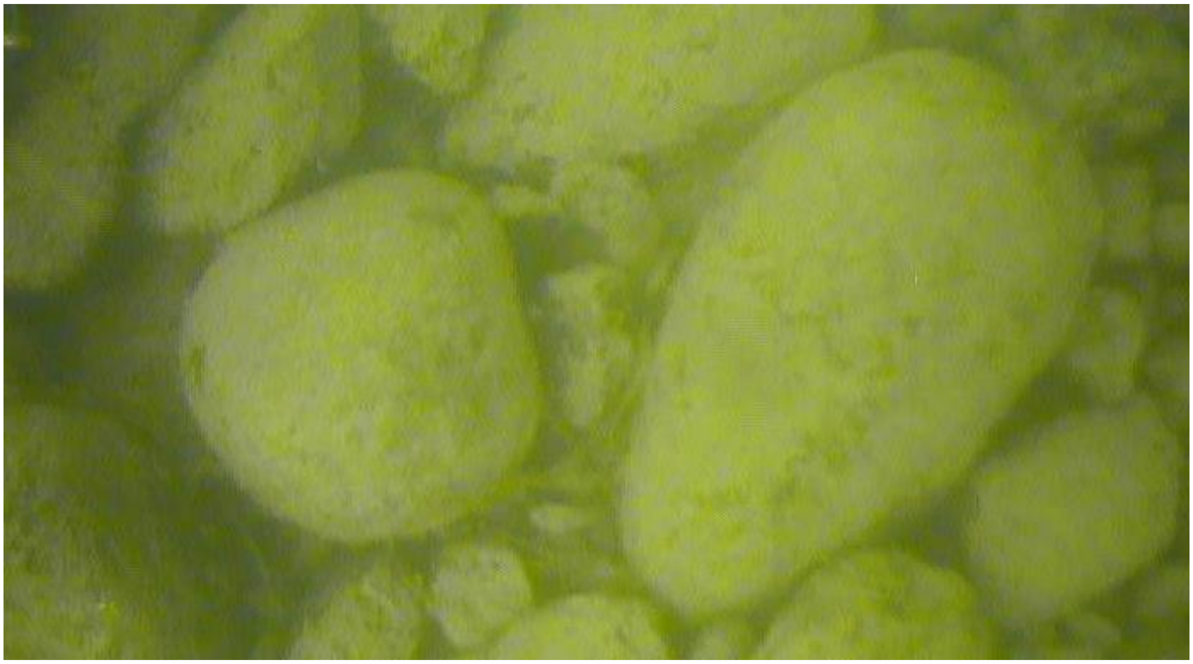

Photo 3: **Cobble bed material at site MP-B during the August sampling trip. Filamentous algae are visible growing on placed substrate and there is not sand present.**

Photo 4: **Underwater photo of substrate from Middle Patch Station MP-D from the October sampling trip. The rope has been partially buried by mobile sediment after the camera was placed.**

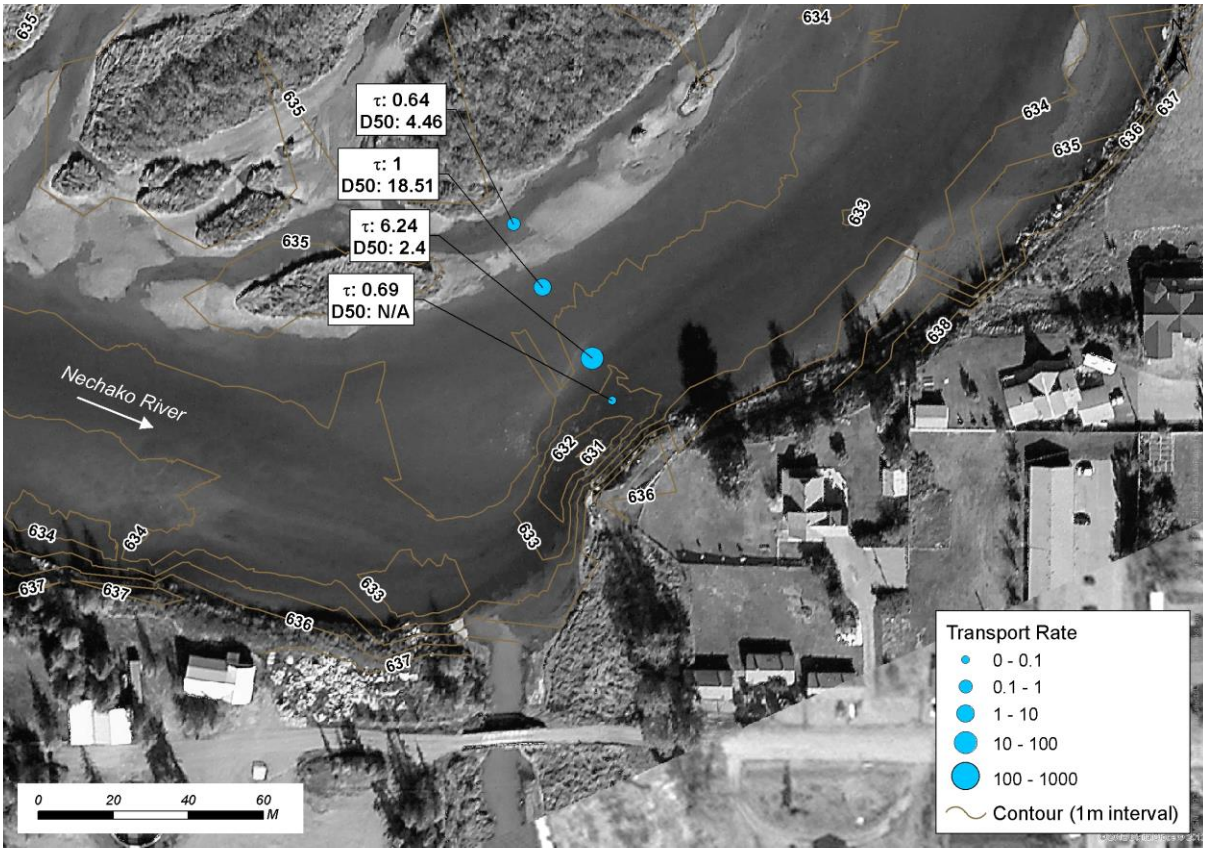

Figure 8: Overview of the sampling sites for the Middle Patch. Shear stress (Pa) and D_{50} (mm) are given for each station. Transport rate (g/m/s) is represented by the size of the circle. The right bank station does not have a D_{50} as no sediment was captured.

4.1.4 LOWER PATCH

The lower patch is located on the outside of a bend just upstream of the Burrard Avenue Bridge. The patch extends upstream to just below the confluence of Murray Creek and extends from moderate depths at the center of the channel to deeper areas along the right bank. The sampling transect was established across the upper portion of the patch **(Figure 9)**. The left side of the channel is deep and has a cobble bed, which is placed material. The right side of the channel is relatively shallow and is a mixed sand and gravel bed.

During the August trip mobile sediment was capture at all sites across the channel, however, there was a large variation across the channel. The first three stations extending into the channel from the inside of the corner had transport rates of 5-6 g/m/s. Station LP-D had a transport rate of 25.2 g/m/s and LP-E spiked at 284.4 g/m/s although these sites had a comparable shear stress to the other sites towards the inside corner where similar bed material is present, which also have similar bed material. The bed material at these locations was almost entirely sand **(Photo 5)**. The two stations closest to the left bank, and over the patch material show a sharp drop in sediment transport with only 1.5 and 0.1 g/m/s, but have a similar shear stress.

During the October trip, shallow water depths made most of the sampling transect inaccessible, so only LP-D, LP-E, LP-F and LP-G could be sampled. No mobile sediment was captured at LP-D or LP-G and LP-E and LP-F had only 0.2 g/m/s each. In comparison to the August trip, there was effectively no sediment transport through this reach. A summary is provided in **Table 5**.

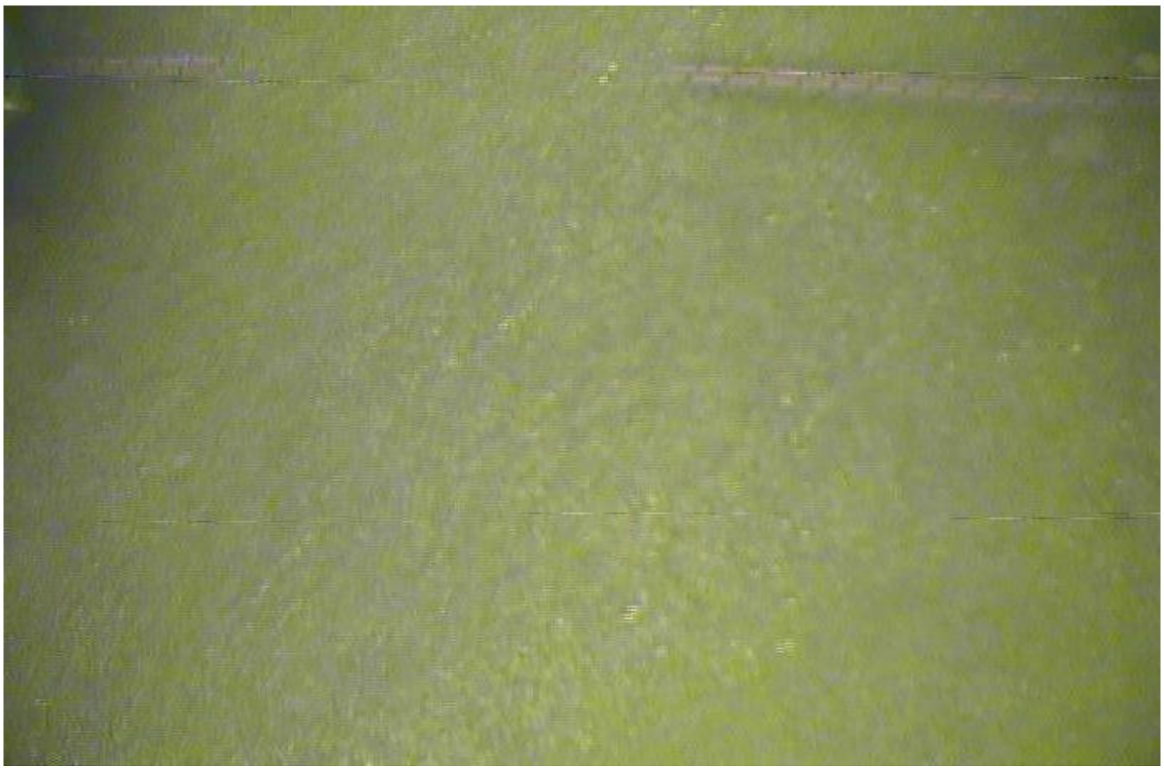

Photo 5: Highly mobile sand bed at LP-E during the August sampling trip. The poor image quality is due to the high flux of sand beneath the camera which is quickly burying the rope at the top edge of the photo.

Photo 6: **Station LP-G during the October sampling. Coarse patch material with sand deposits in the interstices.**

Table 5: **Summary of the Lower Patch Sampling.**

Date	Site	LP-A	LP-B	LP-C	LP-D	LP-E	LP-F	LP-G
August	Mean Velocity (m/s)	1.07	1.19	1.15	1.09	1.08	1.05	0.89
	Depth (m)	2.61	2.49	2.39	2.43	2.55	3.35	3.21
	Near Bed Shear Stress (Pa)	4.02	5.97	6.06	5.22	3.43	9.63	4.73
	Transport Rate (g/s/m)	6.0	5.6	6.2	25.2	284.4	1.5	0.1
October	Mean Velocity (m/s)	-	-	-	0.76	1.16	1.11	0.25
	Depth (m)	-	-	-	0.55	1.15	1.28	1.04
	Near Bed Shear Stress (Pa)	-	-	-	5.21	6.13	7.40	3.13
	Transport Rate (g/s/m)	-	-	-	0.0	0.0	0.0	0.0

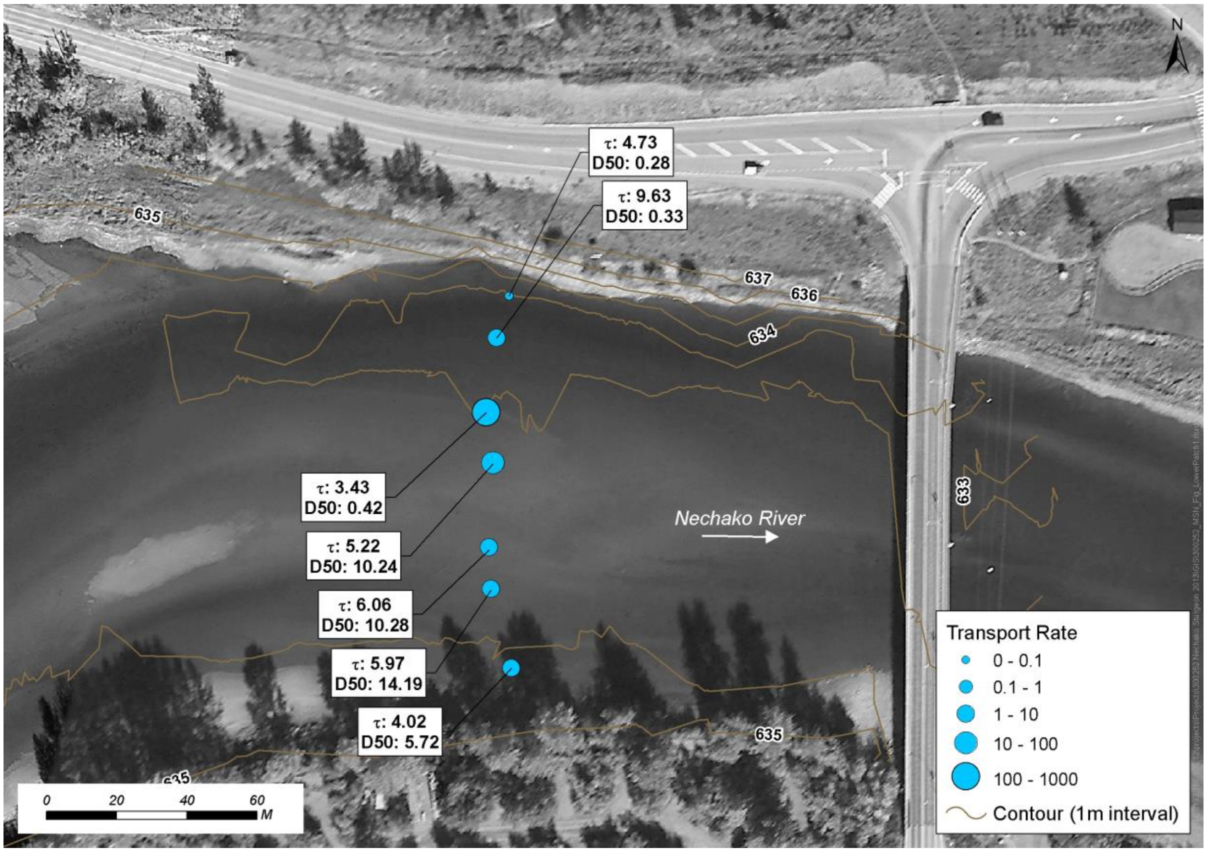

Figure 9: Overview of the sampling sites for the Lower Patch. Shear stress (Pa) and D_{50} (mm) are given for each station. Transport rate (g/m/s) is represented by the size of the circle.

4.1.5 Lower Site

The Lower Site is located a short distance downstream from the Burrard Avenue Bridge. This site was selected as an area of interest as eggs and larvae have been collected here (NHC, 2013a). This site is on a gradual right-hand bend and has a large lateral bar on the right bank. A sampling transect was selected that roughly bisects the area of interest **(Figure 10)**. The bed material along the cross section is primarily sandy gravel

During the August sampling trip mobile sediment was found at all the stations although it was primarily concentrated in the two stations closest to the right bank **(Photo 7)**. Minimal sediment was found to be in transport on the outside of the corner despite having similar bed material and high shear stress **(Table 6)**. This site showed considerably more sediment leaving the study site than was coming in as measured at the upper site. This would mean that the study reach would be expected to be degrading. Overall it does not appear this is occurring[1] and it is likely that sediment must be transported from upstream at another time of the year.

[1] A specific gauge analysis of the WSC gauge located between the two sites would confirm this inference.

During the October sampling trip this was the only site to have significant levels of sediment transport **(Photo 8)**. The sites that showed higher transport rates were in the middle of the transect, however, when the lower water levels are taken into consideration, the transport is still occurring along the inside of the corner. Due to the lower water levels the far right station was not accessible.

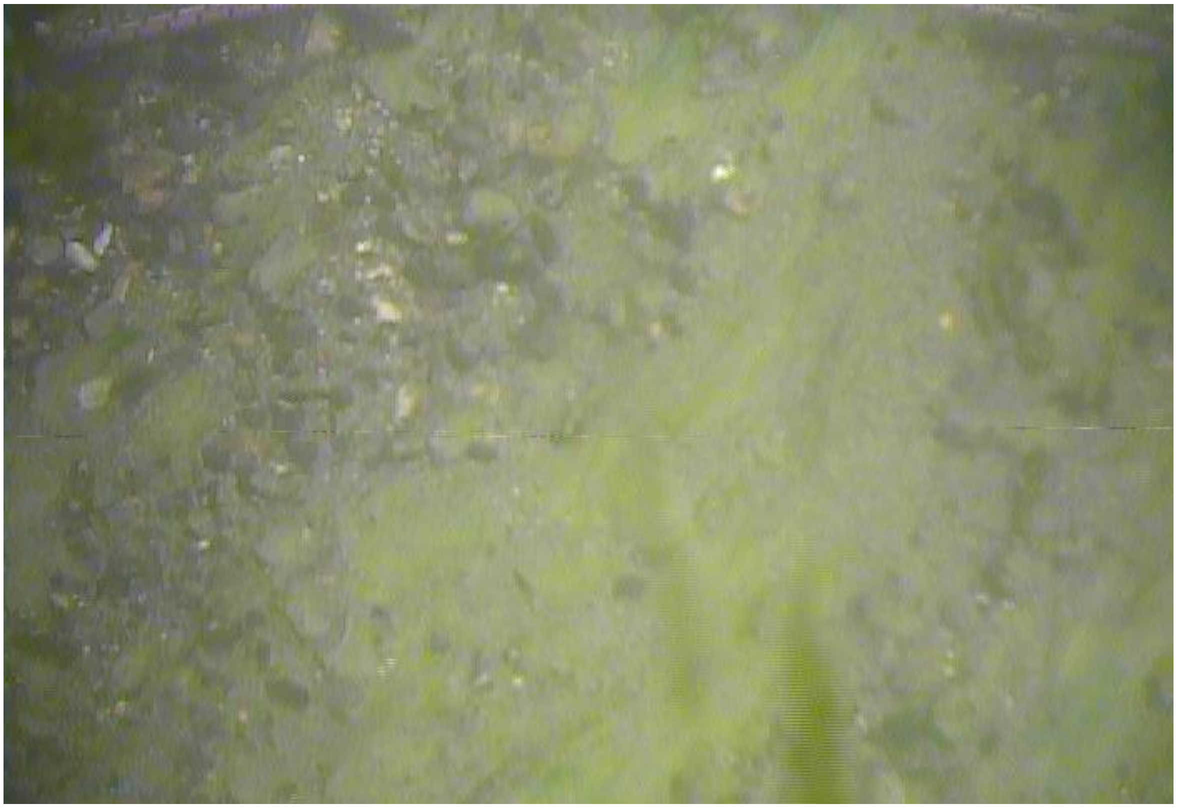

Photo 7: Underwater photo of substrate from LS-E during the August sampling trip.

Figure 10: **Overview of the sampling sites for the Lower Site. Shear stress (Pa) and D_{50} (mm) are given for each station. Transport rate (g/m/s) is represented by the size of the circle.**

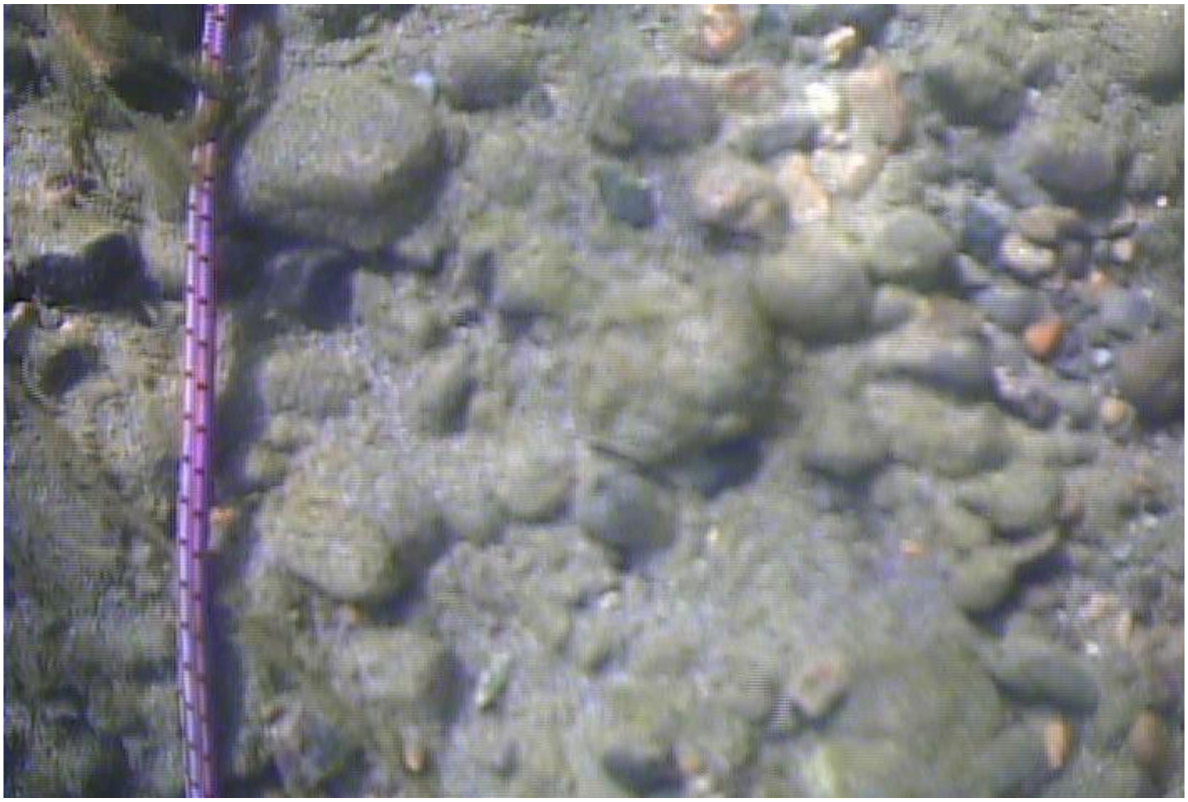

Photo 8: LS-E during the October sampling trip.

Table 6: Summary of the Lower Site sampling.

Date	Site	LS-A	LS-B	LS-C	LS-D	LS-E	LS-F
August	Mean Velocity (m/s)	0.99	1.15	1.14	1.04	0.77	1.15
	Depth (m)	2.52	3.34	3.09	2.51	2.13	3.02
	Near Bed Shear Stress (Pa)	2.62	9.64	5.49	2.66	1.76	4.67
	Transport Rate (g/s/m)	0.1	0.3	7.5	2.2	69.5	33.6
October	Mean Velocity (m/s)	0.47	0.71	0.80	0.66	0.55	-
	Depth (m)	0.69	1.27	1.06	1.02	0.69	-
	Near Bed Shear Stress (Pa)	5.56	6.30	4.25	6.29	1.47	-
	Transport Rate (g/s/m)	0.0	0.0	11.6	8.8	0.1	-

4.1.6 Fort Fraser

As part of the investigation, a transect as completed approximately 60km upstream of the study reach near Fort Fraser, immediately upstream of the Highway 16 crossing. The purpose of this transect was to help constrain the upstream source of the sediment that was being observed in the study reach. High transport rates were found in several stations indicating that the source of sediment is likely further upstream. The bed material at the cross section was primarily sand and a significant portion of the bed was covered in aquatic vegetation **(Photo 9)**. Results from this site are presented in **Table 7**. During the October sampling trip, the Fort Fraser transect was not repeated as sediment sampling at this site is less useful than collecting additional samples in the Vanderhoof Reach.

Table 7: Summary of the data from Fort Fraser. No sampling was conducted at this site in October.

Date	Site	FF-A	FF-B	FF-C	FF-D	FF-E	FF-F
August	Mean Velocity (m/s)	0.59	0.51	0.81	0.81	0.94	0.91
	Depth (m)	2.15	2.35	3.25	3.52	3.58	3.80
	Near Bed Shear Stress (Pa)	4.73	2.03	2.95	5.01	3.11	3.06
	Transport Rate (g/s/m)	1.8	0.9	41.8	106.4	137.8	1.2

Photo 9: Sand bed and vegetation at the FF-A station.

4.2 VELOCITY PATTERNS AT SAMPLING LOCATIONS

Figure 11 shows velocity magnitude at each of the 5 sites where bedload data were collected in August and October, a higher resolution presentation of the same data are provided in **Appendix B**. All of the plots are made using the same velocity scale, and thus they are directly comparable. During the August sampling trip the plots illustrate that the Upper Site had significantly higher velocities and a more symmetric channel cross section than the other sites. A comparison of the sediment transport rates and the velocity at the sites clearly shows that velocity does not correlate with sediment transport. During the October sampling trip the velocities are generally reduced; however, at the middle patch they have increased as the entire flow is going through the site and not through the adjacent island complex. This plot helps illustrate how the pattern of velocity changes discharge changes, which may be important for determining where sturgeon will spawn.

4.3 SUBSTRATE ASSESSMENT AT PLACED PADS

Underwater images of the substrate at the location of the placed pads were collected and processed using the same approach as that which was used in 2012 (NHC, 2013a). Maps showing the condition of the substrate are provided in **Map 1** and **Map 2**. Both maps illustrate that the substrate at the two sites is similar to that which was observed in 2012. At the lower patch there is a small area of high quality substrate free of fines on the outside bend near the downstream end of the patch and the patch is still predominantly cobble. At the middle patch the upstream portion of the substrate, particularly the portion near the right bank remains free of fine sediment and functional. Based on the observations to date, and the sediment transport results the patches are likely to remain at least partially functional for the next few years.

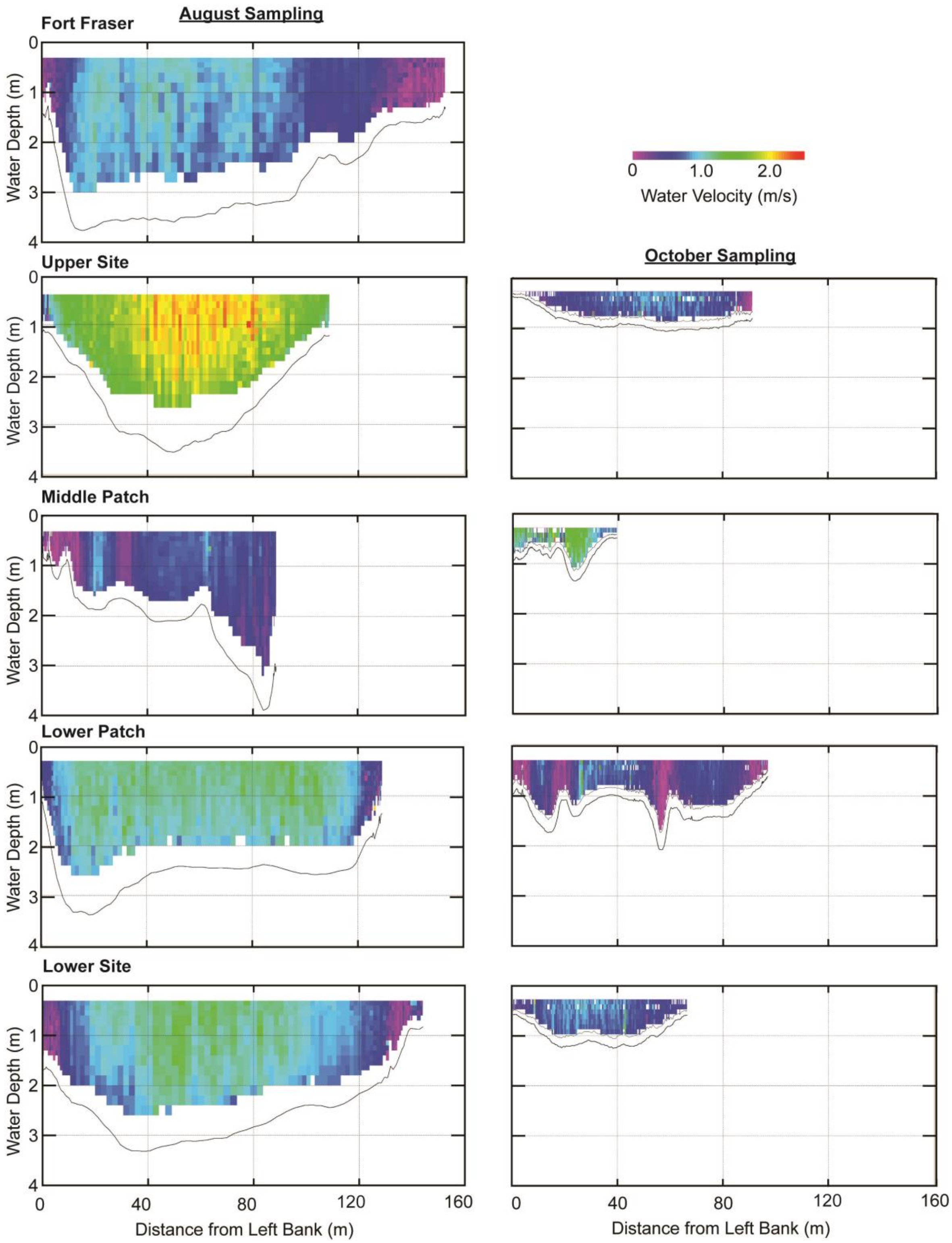

Figure 11: Cross channel pattern of stream velocity magnitude at each of the sampling location.

5 Analysis of Sediment Transport Results

5.1 Sampling Site-Level Observations and Analysis

At the site level we saw that transport rates tended to be highest in the middle portion of the channel where the bed was relatively finer and shear velocities were moderate or high. The outside corner of bends typically had low transport rates. In areas of high transport the material being transported was typically coarse sand, while modest rates of transport were either coarse sand or fine gravel **(Figure 12)**. At low transport rates the bedload was predominately sand. While a detailed analysis of bed substrate was not completed, the general impression was that very high transport rates occurred when the bed was also coarse sand and the full range of bed grain sizes were mobile. At sites dominated by fine gravel and modest transport rates, the bed was commonly also fine gravel. In contrast, areas with coarse gravel typically had low transport rates or modest transport rates that were dominated by coarse sand. A more detailed analysis using the bed images could be conducted to assess the relation between bed grain size, transport and bedload grain size.

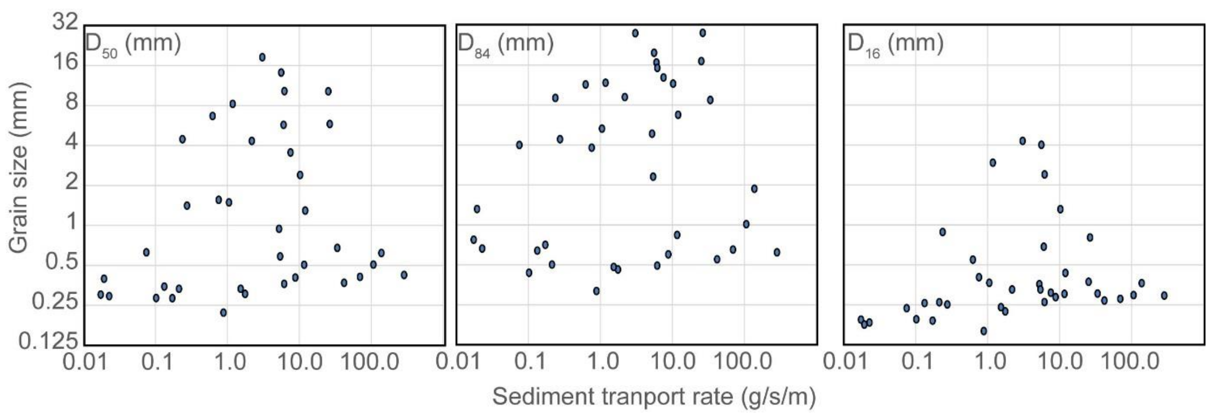

Figure 12: Grain size data for bedload samples as a function of transport rate.

5.2 Between Site Comparison of Transport Rates and Preliminary Sediment Budget Implications

Total sediment transport rates for each of the sites was calculated using the mid-section approach and the results are summarized in **Table 8**. The data are based on measurements made when the discharge was essentially constant, and thus the results can be used to conduct a first order comparison between the sites. The data show that much more sediment was moving at the Lower Site and Lower Patch compared to the Upper Site. This suggests that there must be some within channel storage of sediment that effects the transport rates. The braided island complex is clearly a potential source of sediment.

Table 8: Bedload transport rate at each site during August and October sampling trip.

	Site Cumulative	Fort Fraser	Upper Site	Middle Patch	Lower Patch	Lower Site
Aug-13	Q_s (g/s)	6235	186	245	5793	2308
	Q (m^3/s)	270	331	92	321	316
	Average shear velocity (m/s)	0.06	0.16	0.04	0.07	0.06
Oct-13	Q_s (g/s)	Not Applicable	1	97	4	319
	Q (m^3/s)		48	30	48	45
	Average shear velocity (m/s)		0.06	0.07	0.07	0.07

To attain a first order approximation of the annual sediment yield, the transport rate was assumed to be zero at flows less than 325 m^3/s and equal to the observed rate at flows greater than 325 m^3/s. The results from this analysis are shown in **Table 9** for the average year, and 2011, 2012, and 2013. The analysis suggests that a large volume of sediment may have moved through the Vanderhoof Reach in the last three years. It must however be emphasized that these numbers have a high degree of uncertainty and it is possible that different discharges result in dramatic changes in the transport conditions at the different sites. Even considering the uncertainty, the data do suggest that the transport rates of fine bedload are relatively large. If all the sediment transported past the Lower Patch originated from the island complex in the Vanderhoof reach the bed topography would have reduced by more than 4 cm in 2011 alone. The reach does not however appear to be degrading, suggesting that the sediment moving past the Lower Patch during the August field trip likely moves past the Upper Site when flow conditions are different. Additional sampling will be required to assess when sediment is moved past the Upper Site.

The observation that the largest transport rates were observed at the highway crossing near Fort Fraser indicates that it is unlikely that a one-time pulse of sediment is moving through the system. Rather it appears that the sediment supply is chronic. In comparison to the data provided in **Table 9**, the Cheslta fan is estimated to have introduced 44,000 m^3 of sediment larger than 0.5 mm, this is similar to the amount of sediment transport estimated for 2011 alone at the Fort Fraser site. At this point the preliminary data suggest that bedload sediment from the Cheslta fan are unlikely to be a significant source of the bedload at Vanderhoof. Additional sampling at a wider range of discharge values with more replicates will be needed to improve the transport estimates and confirm this observation.

As part of the 2012 substrate assessment it was estimated than 2 Million m^3 of bedload may have been supplied to the Nechako in the last 50 years[2]. In comparison, the data from Fort Fraser suggest 0.5 Million m^3 of sediment over the same period. Given the uncertainty associated with this science,

[2] The basin area downstream of the Cheslatta fan, but upstream of Vanderhoof, excluding the area upstream of Fraser Lake is approximately 3600 km^2. The bedload yield has been estimated by assuming the suspended sediment yield is 0.7 Mg/km^2/day (Church et al., 1989) and assuming bedload is 10 % of the suspended load.

these numbers are reasonably similar and suggest that general basin wide inputs may result in the observed transport rates.

Table 9: Annual bedload sediment yield inferred from August samples

Annual yield (m^3)	Fort Fraser	Upper Site	Middle Patch	Lower Patch	Lower Site
Average 2013-1957	10901	326	428	10129	4035
2011	43028	1285	1691	39980	15927
2012	39979	1194	1571	37147	14798
2013	5421	162	213	5037	2007

6 Conclusions and Recommendations

The bedload transport sampling investigations demonstrated that fine gravel and coarse sand is mobile at relatively low flows in the Vanderhoof Reach. The data also show that sediment transport tends to be concentrated towards the center and inside corner portion of the channel, and transport rates are low or zero on the outside edge of the channel. This pattern of transport corresponds well with the observed infilling pattern at the placed substrate locations. Furthermore, the observations suggest that if the hydraulics and sediment transport patterns are appropriate, placed substrate may remain relatively clear of fines for a number of years. Substrate assessments in 2011, 2012 and 2013 have shown that the portions of the placed substrate have remained free of fine sediment.

The discharge and shear stress data, coupled with the observed transport rates shows that transport rates are not directly related to flow and shear, but within channel storage and local reworking of stored sediment is also factor. The initial sediment budget analysis suggests that the timing of sediment transport at the different sites varies, and it remains unclear when bedload is transported into the Vanderhoof Reach.

On account of the observations to date the following recommendations were developed:

1. More bedload sampling at different flows and different times of the year for the Upper Site and Lower Patch. The sampling program should be developed to construct a bedload rating curve for each of the sites.
2. A windlass winch and larger anchor be installed on the boat used to conduct the sampling to improve the efficiency and safety of the sampling program, especially at higher flows.
3. The condition of the substrate at the Middle and Lower Patch should continue to be conducted on an annual basis using underwater photo surveys.
4. A one-time upstream bedload transport sampling program be initiated during high flows to help constrain the upstream source of the sediment entering the study reach.

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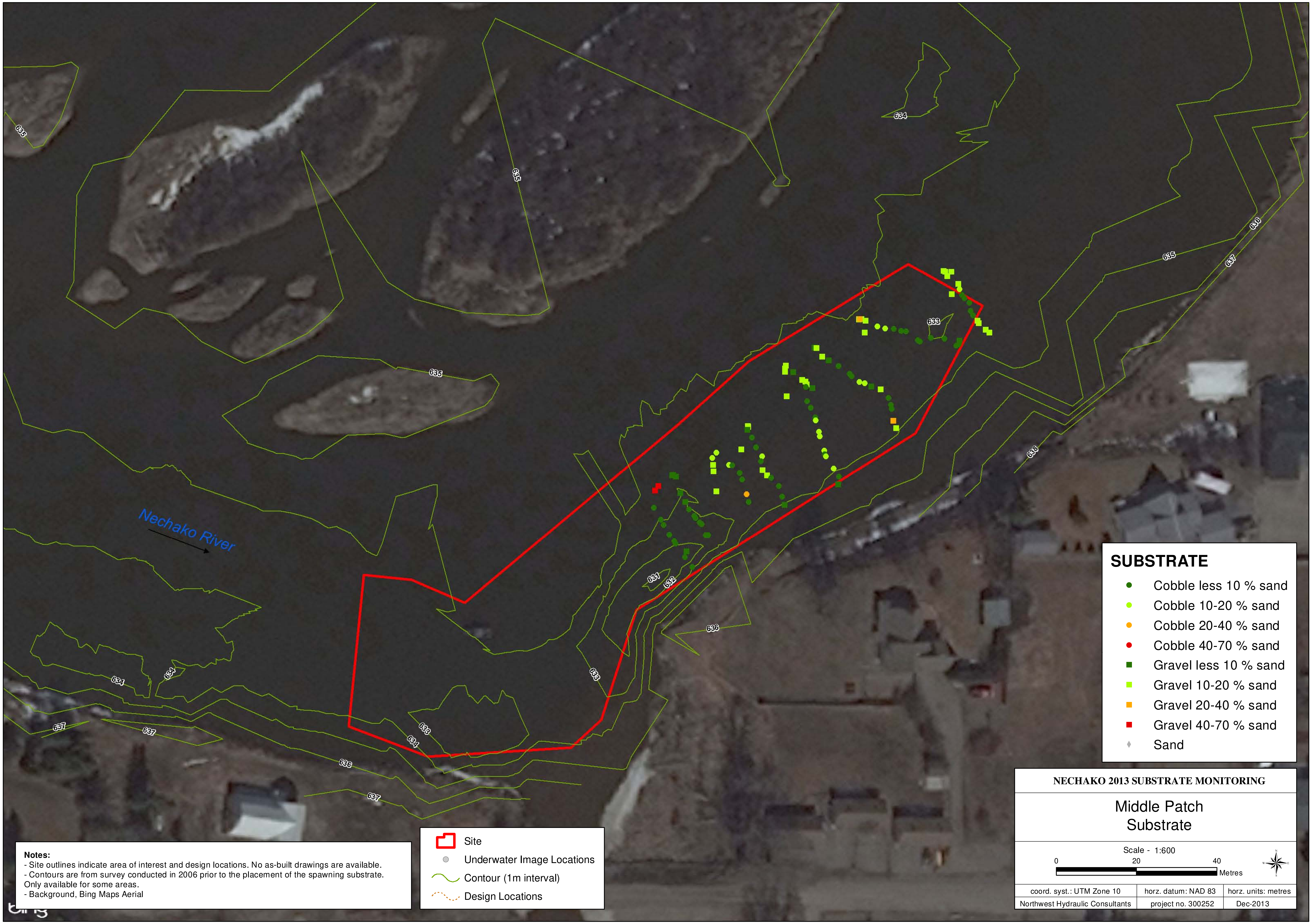
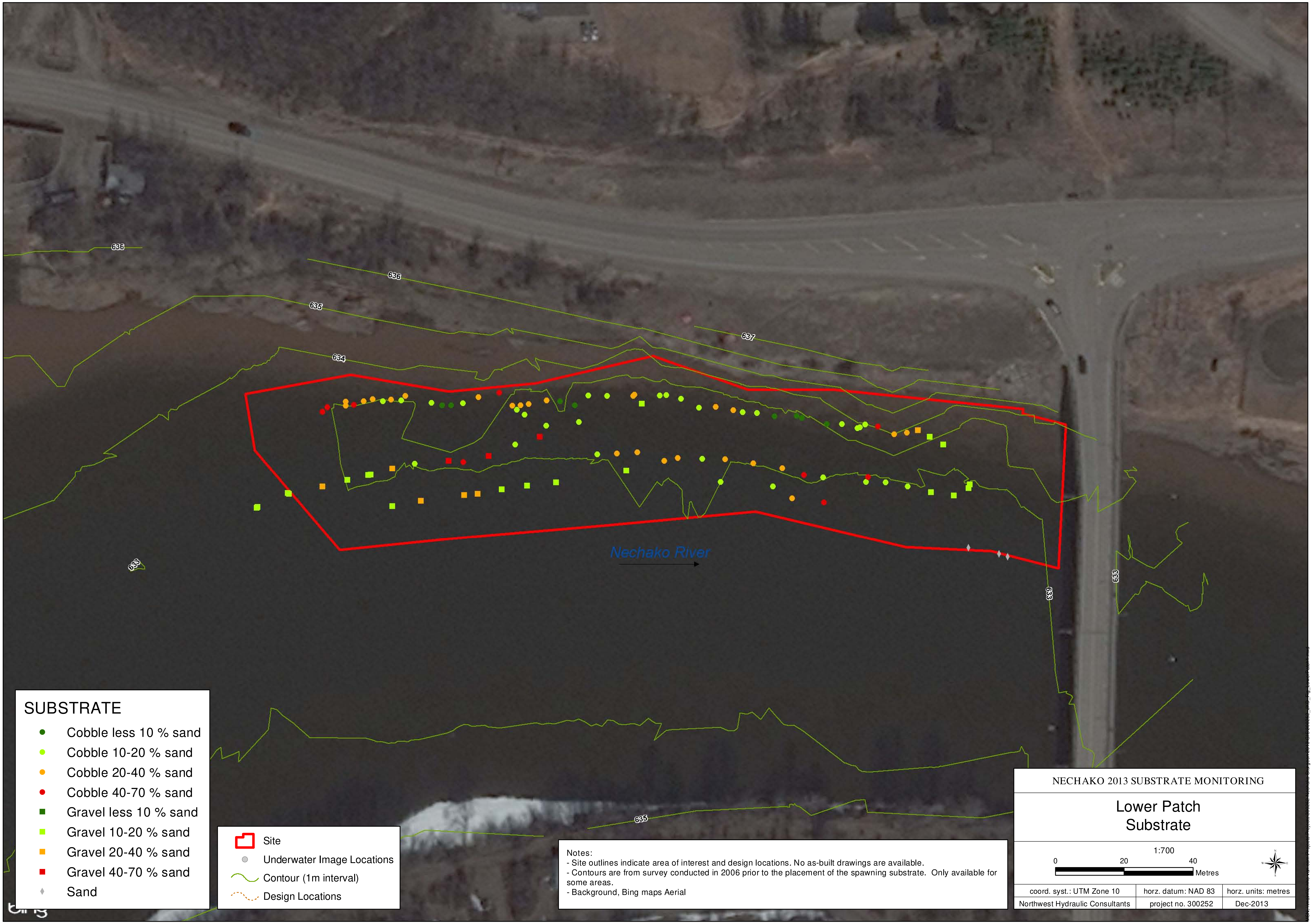
MAPS


Nechako River
SUBSTRATE
Cobble less 10 % sand
Cobble 10-20 % sand
Cobble 20-40 % sand
Cobble 40-70 % sand
Gravel less 10 % sand
Gravel 10-20 % sand
Gravel 20-40 % sand
Gravel 40-70 % sand
Sand
NECHAKO 2013 SUBSTRATE MONITORING
Middle Patch
Substrate
Scale - 1:600
0
20
40
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
Northwest Hydraulic Consultants
project no. 300252
Dec-2013
Site
Underwater Image Locations
Contour (1m interval)
Design Locations
Notes:
- Site outlines indicate area of interest and design locations. No as-built drawings are available.
- Contours are from survey conducted in 2006 prior to the placement of the spawning substrate. Only available for some areas.
- Background, Bing Maps Aerial

Map 1



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Nechako River
SUBSTRATE
Cobble less 10 % sand
Cobble 10-20 % sand
Cobble 20-40 % sand
Cobble 40-70 % sand
Gravel less 10 % sand
Gravel 10-20 % sand
Gravel 20-40 % sand
Gravel 40-70 % sand
Sand
Site
Underwater Image Locations
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- Site outlines indicate area of interest and design locations. No as-built drawings are available.
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- Background, Bing maps Aerial
NECHAKO 2013 SUBSTRATE MONITORING
Lower Patch
Substrate
1:700
0
20
40
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
Northwest Hydraulic Consultants
project no. 300252
Dec-2013

Map 2

northwest hydraulic consultants

APPENDIX A

SEDIMENT TRANSPORT DATA

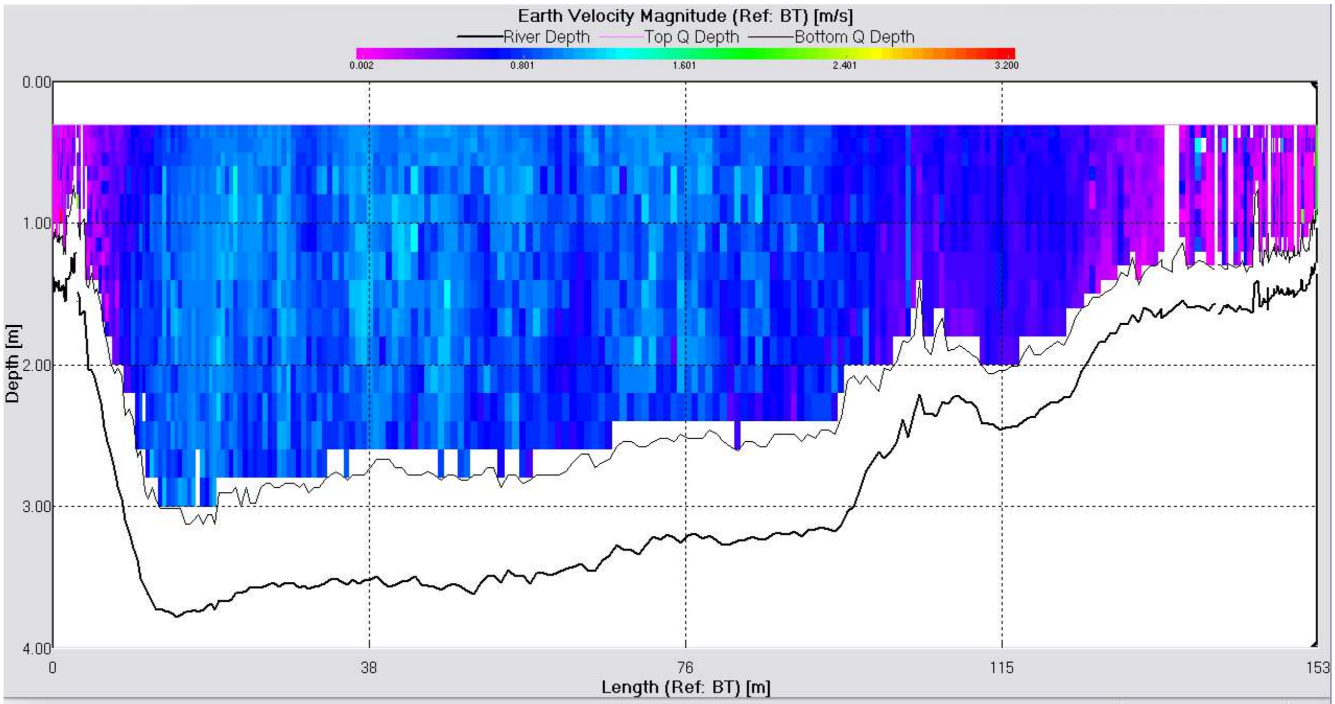
nhc
northwest hydraulic consultants

Date Sample Collected	Sample name	Northing (m)	Easting (m)	Transport rate (g/s/m)	Cumulative Per Cent Finer Than; Grain size class are in mm																				D50 (mm)	D84 (mm)	D16 (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			
8/16/2013	FF-A	5991295	397197	1.8	100	100	100	100	100	100	100	100	100	100	100	98	96	88	70	23	2	0	0	0	0.31	0.46	0.22
8/16/2013	FF-B	5991297	397175	0.9	100	100	100	100	100	100	100	100	100	100	100	100	100	99	92	65	23	0	0	0	0.22	0.32	0.16
8/16/2013	FF-C	5991295	397160	41.8	100	100	100	100	100	100	100	100	100	100	100	98	95	80	45	8	1	0	0	0	0.37	0.55	0.27
8/16/2013	FF-D	5991295	397143	106.4	100	100	100	100	100	100	100	99	98	95	92	84	71	49	26	7	1	0	0	0	0.51	1.01	0.30
8/16/2013	FF-E2	5991296	397120	137.8	100	100	100	99	99	99	97	95	90	85	80	72	59	35	14	2	0	0	0	0	0.62	1.87	0.36
8/16/2013	FF-F	5991291	397098	1.2	100	100	100	100	82	47	31	24	15	10	9	8	7	4	2	1	0	0	0	0	8.23	11.77	2.95
8/15/2013	LP A	5986886	433772	6.0	100	100	100	82	70	63	50	39	30	25	23	20	16	12	7	2	1	0	0	0	5.72	16.72	0.68
8/15/2013	LP B	5986909	433766	5.6	100	100	100	58	35	27	20	16	12	10	8	7	6	4	2	1	0	0	0	0	14.19	19.82	4.02
8/15/2013	LP C	5986920	433766	6.2	100	100	100	89	56	35	29	22	17	15	12	9	6	4	2	1	0	0	0	0	10.28	15.22	2.40
8/15/2013	LP D	5986944	433767	25.2	100	100	92	82	53	43	36	33	30	28	27	25	24	21	15	4	0	0	0	0	10.24	17.16	0.37
8/15/2013	LP E2	5986959	433765	284.4	100	100	100	100	100	100	100	100	100	100	100	98	93	69	30	4	0	0	0	0	0.42	0.62	0.29
8/15/2013	LP F	5986980	433768	1.5	100	100	100	100	100	100	100	100	100	100	100	99	98	87	57	18	3	2	2	2	0.33	0.48	0.24
8/15/2013	LP G	5986992	433771	0.1	100	100	100	100	100	100	100	100	100	100	98	95	93	89	76	35	9	5	5	5	0.28	0.44	0.19
8/15/2013	LS A	5986800	434170	0.1	100	100	100	100	100	100	100	84	73	67	62	57	53	45	35	19	3	0	0	0	0.63	4.01	0.24
8/15/2013	LS B	5986787	434160	0.3	100	100	100	100	100	100	91	81	71	58	50	43	38	33	27	16	3	0	0	0	1.41	4.42	0.25
8/15/2013	LS C	5986765	434152	7.5	100	100	100	92	79	67	59	52	46	42	39	35	31	25	19	11	2	0	0	0	3.54	12.91	0.31
8/15/2013	LS D	5986745	434123	33.6	100	100	100	97	90	82	72	66	61	58	55	53	51	44	26	4	0	0	0	0	0.68	8.74	0.30
8/15/2013	LS E	5986732	434101	2.2	100	100	100	100	100	73	57	48	41	34	31	28	26	23	18	8	2	0	0	0	4.33	9.18	0.33
8/15/2013	LS F	5986760	434133	69.5	100	100	100	99	99	98	97	96	95	95	94	93	89	69	36	8	1	0	0	0	0.41	0.65	0.28
8/15/2013	MP-C	5986336	433324	10.2	100	100	100	94	83	80	74	69	60	39	18	7	5	5	4	3	1	0	0	0	2.40	11.60	1.31
8/15/2013	MP-D3	5986355	433311	3.1	100	100	60	43	26	17	17	16	15	14	13	12	11	10	8	3	0	0	0	0	18.51	27.82	4.30
8/15/2013	MP-E	5986372	433303	0.2	100	100	100	100	100	75	55	48	32	26	22	18	13	6	3	2	1	0	0	0	4.46	9.06	0.88
8/14/2013	US-1	5986116	431758	26.4	100	92	71	69	64	57	49	43	36	30	25	19	14	8	4	1	0	0	0	0	5.81	27.99	0.80
8/14/2013	US-2	5986151	431868	12.0	100	100	100	95	90	87	81	76	69	60	53	42	32	20	11	3	0	0	0	0	1.30	6.75	0.44
8/15/2013	U/S A	5986144	431750	6.1	100	100	100	100	100	100	100	100	100	100	100	100	99	86	47	11	1	1	1	1	0.36	0.49	0.26
8/15/2013	U/S B	5986128	431775	5.2	100	100	100	100	93	90	86	81	74	67	61	52	41	27	16	6	0	0	0	0	0.94	4.87	0.36
8/15/2013	U/S-C	5986109	431757	0.8	100	100	100	100	100	100	93	86	73	60	46	34	26	19	14	7	1	0	0	0	1.56	3.82	0.40
8/15/2013	U/S D	5986088	431756	0.6	100	100	100	100	84	55	45	37	33	32	29	25	20	15	12	7	1	0	0	0	6.67	11.43	0.55
8/15/2013	U/S E	5986113	431757	1.1	100	100	100	100	100	93	85	79	66	56	49	39	30	22	15	6	1	0	0	0	1.49	5.31	0.37
10/11/2013	Cumulative_US	Not Applicable		0.0	100	100	100	100	100	100	100	100	100	100	95	88	82	73	64	34	10	0	0	0	0.30	0.77	0.19
10/12/2013	LP-D	5986962	433780	0.0	100	100	100	100	100	100	100	100	100	100	100	93	85	78	66	36	13	2	2	2	0.29	0.66	0.18
10/12/2013	LP-E	5986975	433777	0.2	100	100	100	100	100	100	100	100	100	100	100	99	96	84	58	10	1	0	0	0	0.33	0.50	0.26
10/12/2013	LP-F	5986982	433771	0.2	100	100	100	100	100	100	100	100	95	93	91	88	84	79	73	37	10	0	0	0	0.28	0.71	0.19
10/12/2013	LS-B	5986787	434158	0.0	100	100	100	100	100	100	100	100	100	100	85	78	66	55	47	37	16	1	0	0	0.40	1.32	0.18
10/12/2013	LS-C	5986773	434148	11.6	100	100	100	100	100	100	98	97	96	96	95	91	77	49	25	5	1	0	0	0	0.51	0.84	0.30
10/12/2013	LS-D	5986763	434137	8.8	100	100	100	100	100	100	99	99	98	98	97	96	93	74	35	4	0	0	0	0	0.40	0.60	0.29
10/12/2013	LS-E	5986753	434127	0.1	100	100	100	100	100	100	100	100	100	100	94	91	87	76	52	13	5	1	0	0	0.35	0.64	0.26
10/10/2013	MP-D	5986336	433327	5.4	100	100	100	100	100	96	93	90	87	82	77	70	60	42	20	3	1	0	0	0	0.58	2.31	0.33

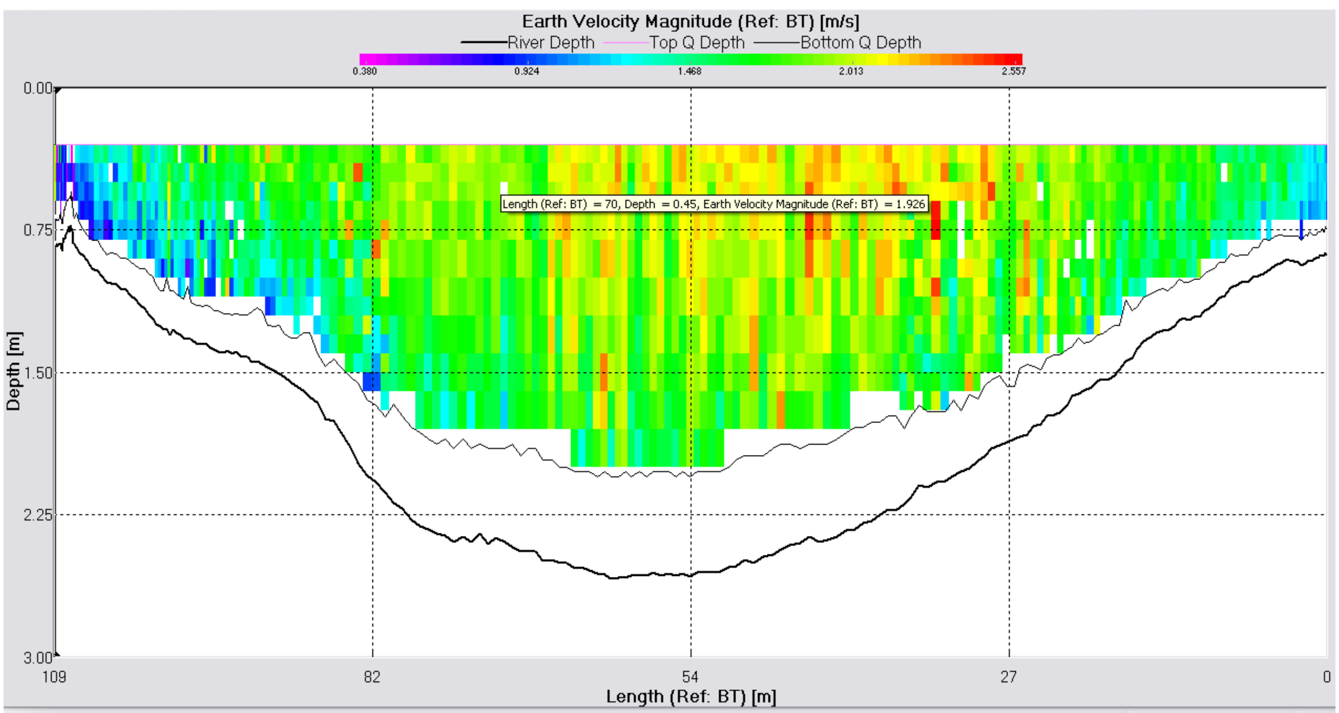
nhc
northwest hydraulic consultants

APPENDIX B

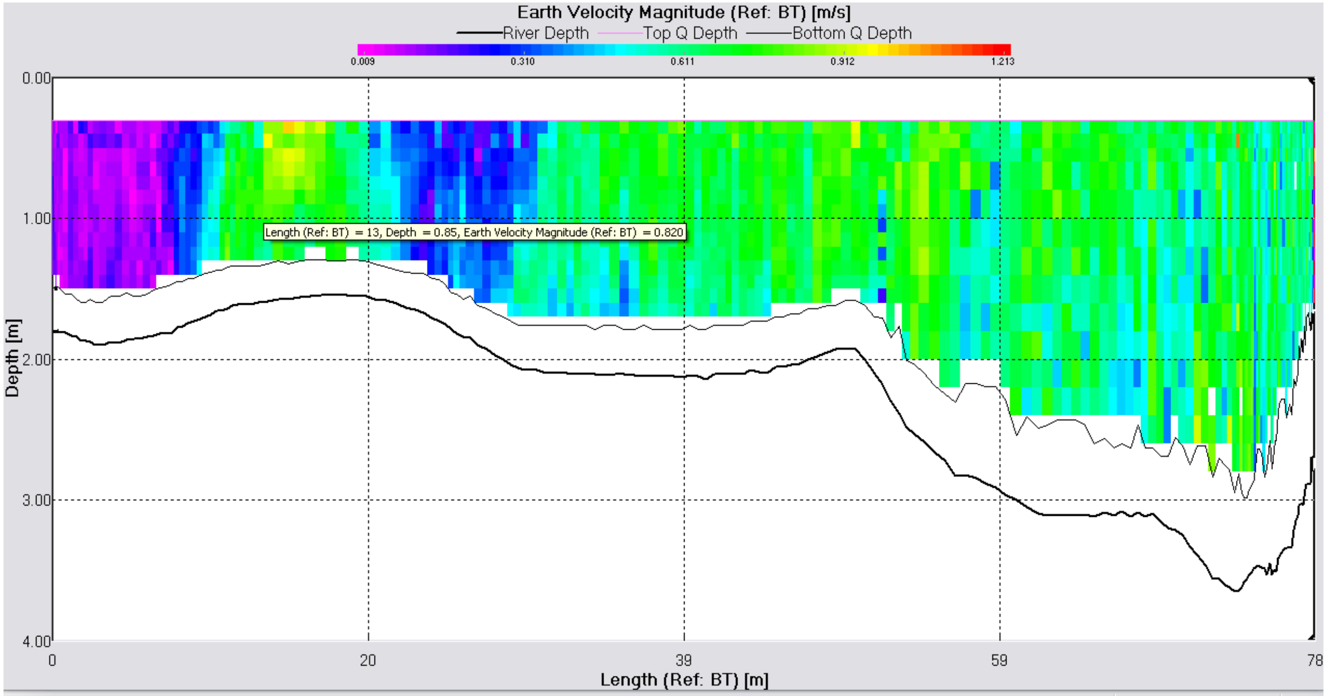
ADCP TRANSECTS



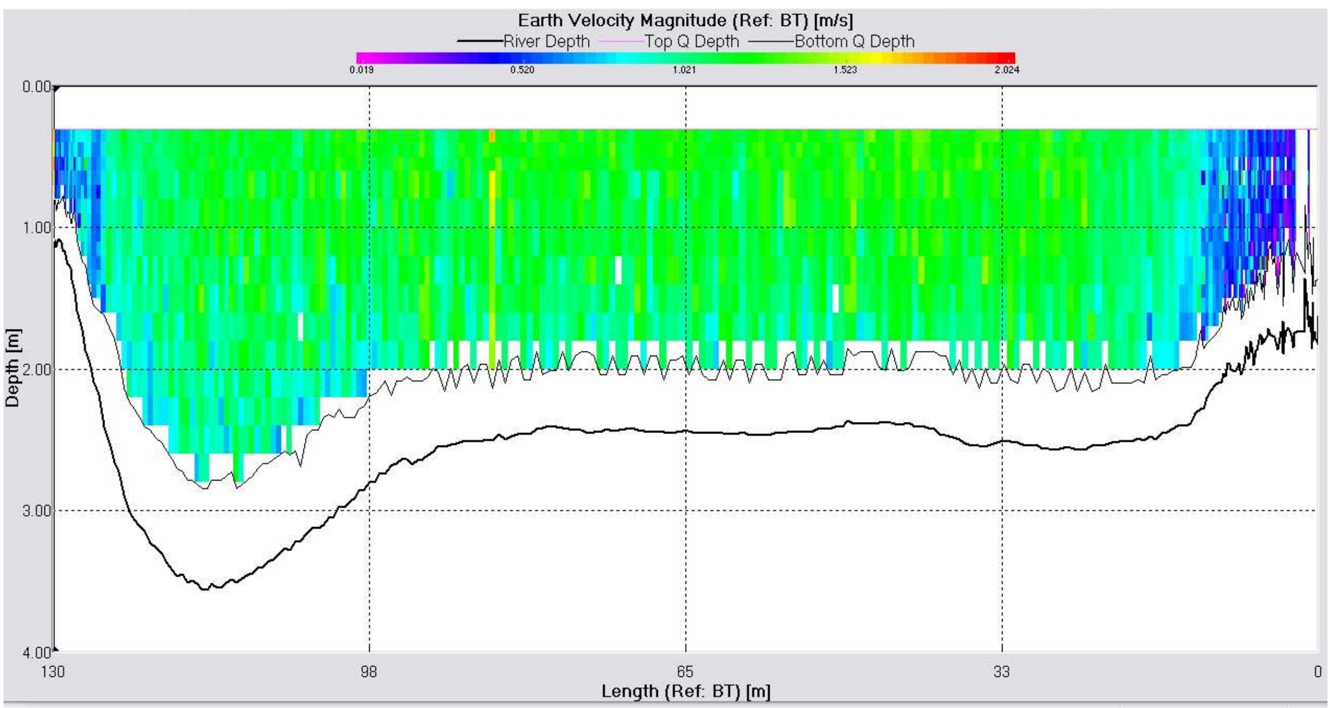
August 2013 discharge transect for Fort Fraser (Q = 270 m3/s)



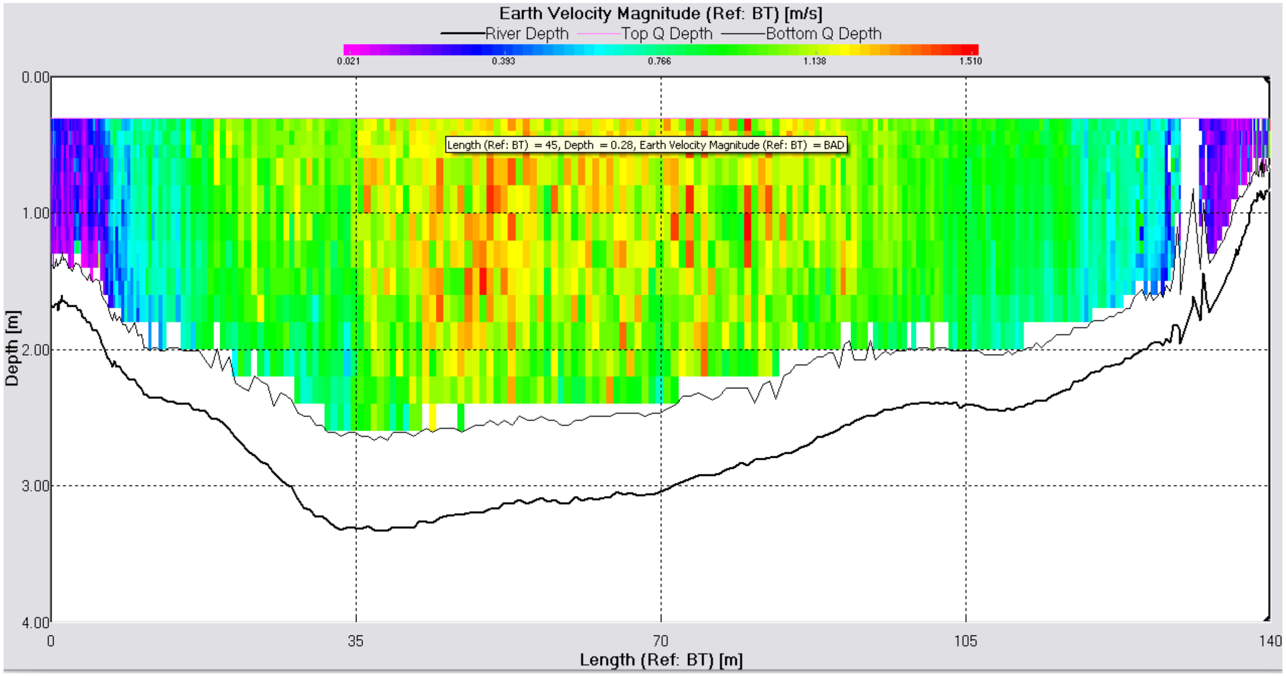
August 2013 discharge transect for the Upper Site. (Q = 332m^3/s)



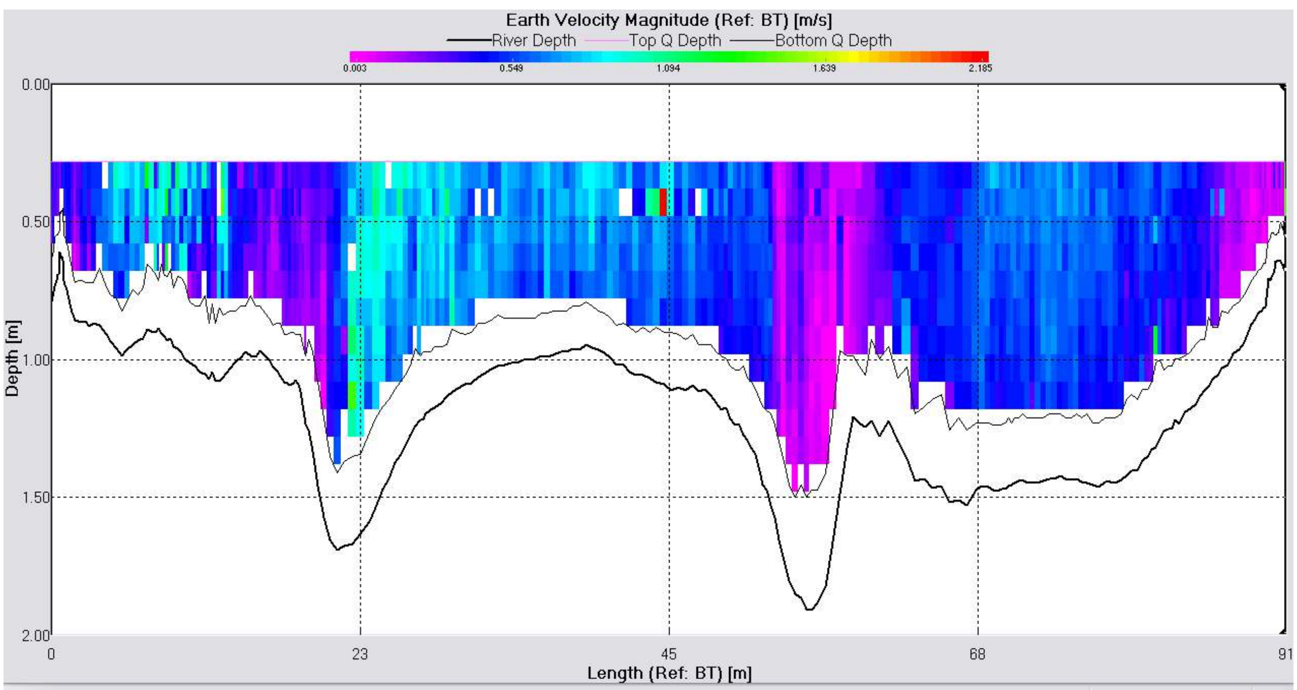
August 2013 discharge transect for the Middle Patch. (Q = 92m³/s)



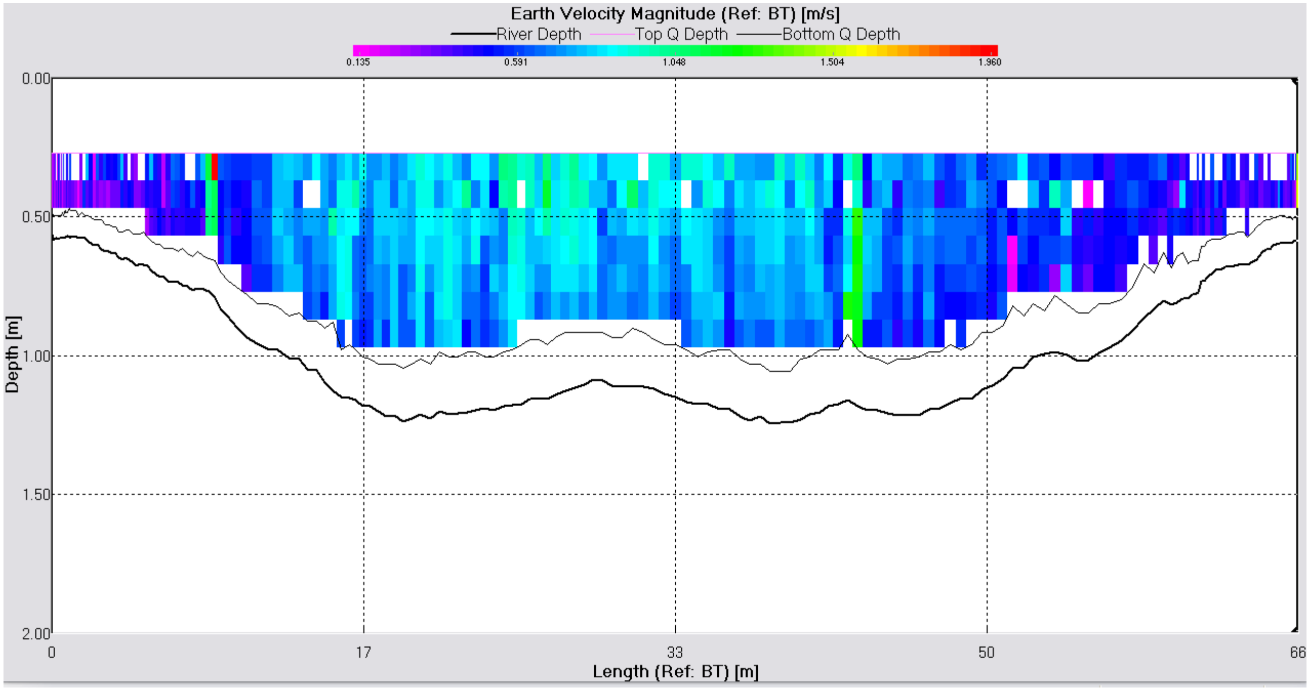
August 2013 discharge transect for the Lower Patch. (Q = 320m³/s)



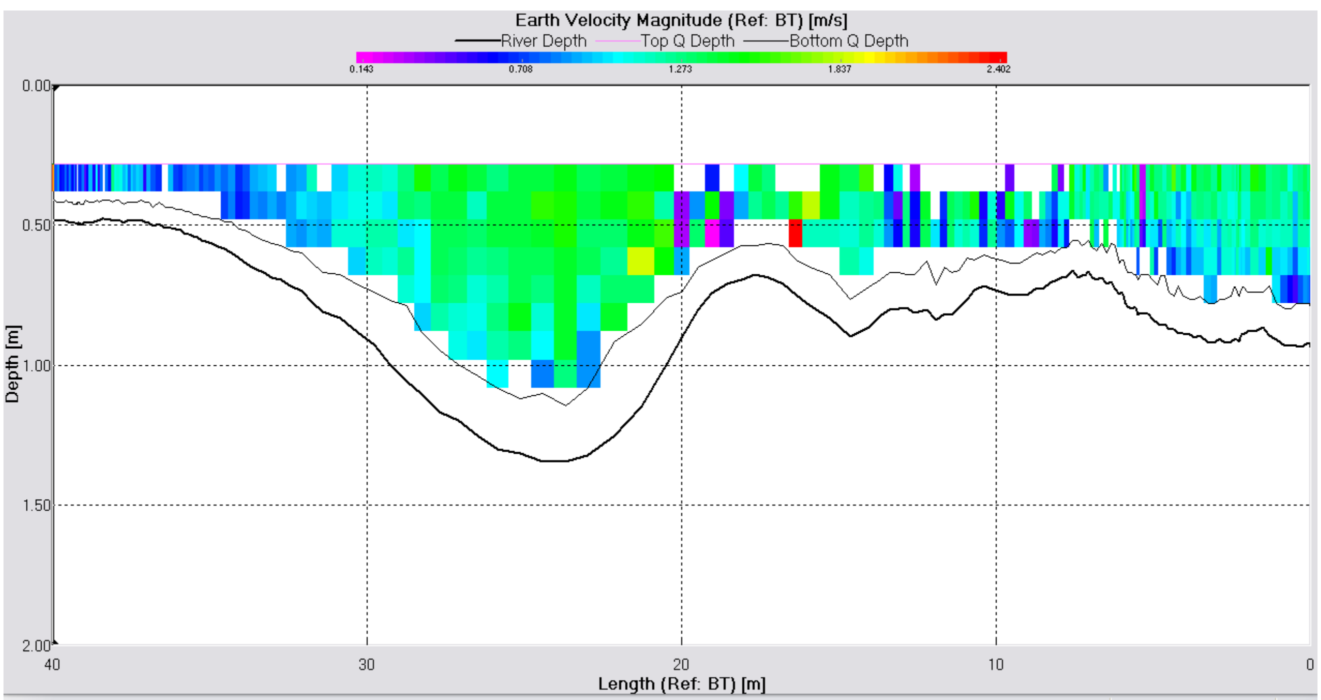
August 2013 discharge transect for the Lower Site. (Q = 315m³/s)



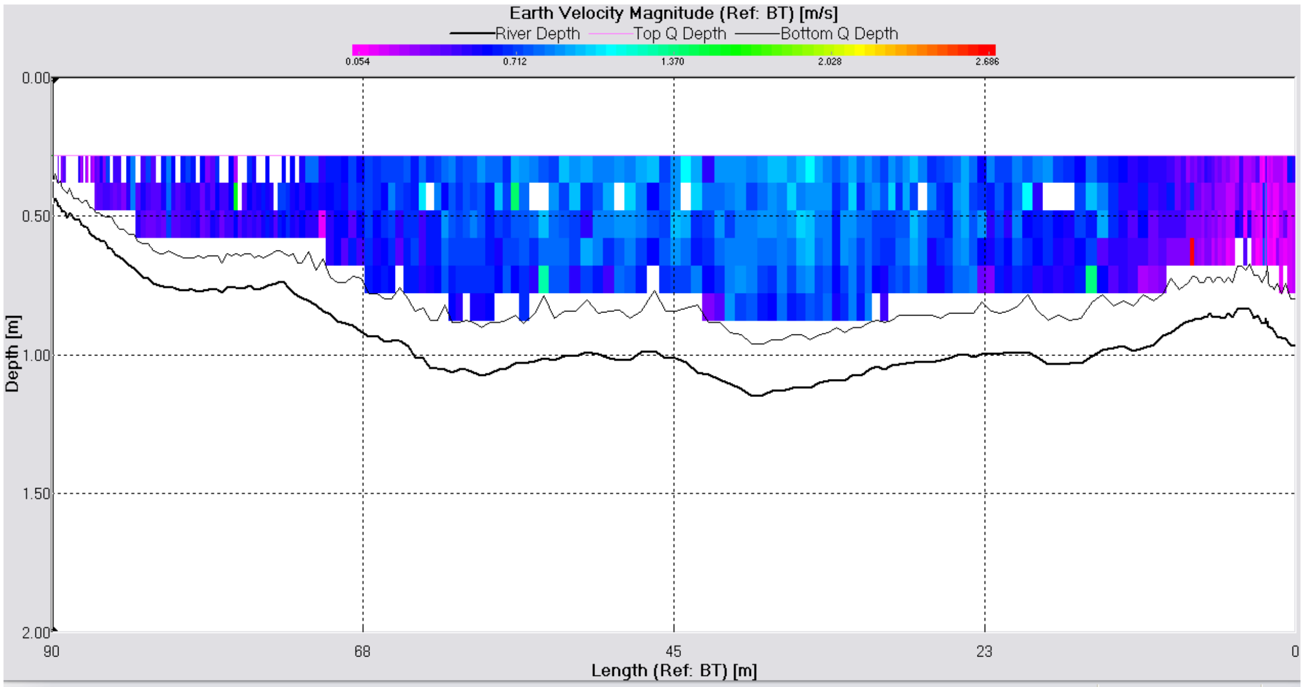
October 2013 discharge transect for the Lower Patch. (Q = 48m³/s)



October 2013 discharge transect for the Lower Site. (Q = 45m³/s)



October 2013 discharge Transect for the Middle Patch. (Q = 30m³/s)



October 2013 discharge Transect for the Upper Site. (Q = 48m³/s)