Nechako Sturgeon Spawning Gravel September 2012 Substrate Assessment

BRITISH COLUMBIA

Ministry of Forests, Lands and Natural Resource Operations
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EXECUTIVE SUMMARY

As part of the ongoing sturgeon recovery effort that is underway for the Nechako River, Northwest Hydraulic Consultants Ltd. (NHC) conducted a substrate assessment at four locations near Vanderhoof BC. Coarse substrate was placed at two of the sites in May 2011 and the quality of the substrate was the primary purpose of the assessment. Of particular interest was whether interstitial spaces between the stones that may provide refuge for sturgeon eggs and larvae still exist. A secondary objective was to evaluate the condition of the substrate at a downstream site where a large number of eggs was found in the spring of 2012, and the condition of the substrate at an upstream site that was historically used for spawning. For the purposes of this report the placed material sites have been labelled the Middle and Lower Patch, while the natural substrate sites have been labelled the Upper and Lower Site.

The assessment was conducted with Ministry of Forests, Lands and Natural Resource Operations personnel and boat and driver support supplied by EDI Environmental Dynamics Inc. The assessment consisted of taking freeze core samples of the substrate and collecting underwater images of the substrate. Visual inspection of the freeze cores and underwater images was used to identify if the interstitial spaces between the placed stones had filled with fine sediment.

The freeze cores and underwater images demonstrate that good quality substrate exists at the Upper Site and the Middle and Lower Patches. The Lower Site has a distinct lack of cobble substrate and the substrate is generally of marginal quality; some interstitial spaces do exist between gravel grains, but these spaces are smaller those found at the three upstream sites.

The upstream most site is the only location with naturally occurring cobble substrate and the substrate is quite imbricated. There does not appear to be sufficient energy to move these cobbles to the downstream areas. At the Middle Patch some infilling has occurred on the patches, and some filamentous algae is growing in other areas but nevertheless, the downstream portion of the patch remains free of fines and functional. The 2012 field work revealed that the Lower Patch is in better condition than expected. A large proportion of the placed substrate along the left bank side of the channel is free of fine sediment and the placed substrate remains functional. The right bank side of the placed material does have areas that were extensively infilled with fines. The placed material at both sites does not show any signs of being moved due to the 2011 and 2012 freshets. The Lower Site is predominantly gravel and has more sand than any of the other sites, as such it has the poorest substrate quality.

Based on the site investigations the quality of the substrate in the region could possibly be improved by hydraulically cleaning the Upper Site and placing cobble substrate at the Lower Site. At this time the two placed patches appear to be functioning reasonably well and remedial work does not appear warranted. A decision to place substrate at the Lower Site should only be done after considering all of the biological, geomorphic and potential flooding implications. Of particular interest is why the sturgeons appear to be spawning further downstream now compared to before, and if placing substrate at the Lower Site could result in a change in their spawning behaviour.

NOTIFICATION

CITATION

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CERTIFICATION

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▪ Wayne Salewski	Vanderhoof BC
▪ Neil and others	Fisheries Program of the Carrier Sekani Tribal Council

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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 September 2011, Northwest Hydraulic Consultants Ltd. (NHC) conducted an assessment of the two patches of sturgeon spawning substrate that were placed in the Nechako River. The primary purpose of the work was to assess the condition of the substrate. The results of this study were presented in a report entitled "*Nechako Sturgeon Spawning Gravel - September 2011 Substrate Assessment*" (Northwest Hydraulic Consultants Ltd., 2012).

Following the 2012 freshet, NHC conducted a new substrate condition assessment in the two locations visited in 2011 and two other sturgeon spawning key sites (Figure 1). This document outlines the assessment approach and describes the substrate conditions observed in late September 2012. The work was completed with support from Ministry of Forests, Lands and Natural Resource Operations personnel. Boat and driver support was supplied by EDI Environmental Dynamics Inc., Wayne Salewski and the Fisheries Program of the Carrier Sekani Tribal Council (the latter two provided last minute boat support after a mechanical failure on the EDI boat).

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. Northwest Hydraulic Consultants Ltd., 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 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 (Northwest Hydraulic Consultants Ltd., 2006 is particularly relevant). These investigations have revealed the following (as summarized in Northwest Hydraulic Consultants Ltd., 2012):

- The spawning reach occurs at a distinct reduction in channel gradient (0.06 % upstream to 0.03 % downstream (Northwest Hydraulic Consultants Ltd., 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 (Northwest Hydraulic Consultants Ltd., 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 (Northwest Hydraulic Consultants Ltd., 2009).
- Sand and fine gravel from the Cheslatta avulsions have moved 30 to 40 km downstream of Vanderhoof (Northwest Hydraulic Consultants Ltd., 2003).
- As ice melted at the end of the last major glaciation, glaciated lakes and deltas formed and these deposited clays, silts and sands on the landscape resulting in the formation of the Nechako plains (Armstrong and Tipper, 1948; Holland, 1976). Given the agricultural and forestry land-use in the area, and the fine grained nature of the deposits, the uplands likely contribute suspended and bedload sediments to the Nechako River.
- Regional sediment yield data suggest that over the last 50 years, 2 million cubic meters of bedload may have been supplied to the Nechako River upstream of Vanderhoof[1]. This contribution is similar in magnitude to the contribution from the Cheslatta fan.

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 Cheslatta fan and the upstream watershed. Flow regulation and channel confinement have likely increased the deposition of sediment in the reach.

1.2 Study Rationale and Approach

The primary purpose of the study is to determine the substrate type (cobble/gravel/sand) and the amount of infilling of the spaces between the grains. If the spaces between the grains appear open, it is also useful to know at what depth they become filled. In general, water depths at the sites range from 0.7 to 2 meters and it is not possible to stand in the channel and directly assess the substrate. Instead a multi-pronged approach is used. To quickly determine the substrate type and whether the spaces between the larger grains are filled with fines an underwater camera combined with a GPS was used. This approach only enables the surface of the river bed to be assessed. To attain an understanding of the substrate condition at various depths freeze core samples were collected. Finally, to confirm that the underwater camera images were capturing the general pattern of the substrate, and to gain an understanding of the topography and active processes in the channel, one site was assessed by snorkelling.

Within the report the Wentworth scale is used to describe substrate size. For reference, the scale is provided in Table 1. Grain size classification is based on the length of the b-axis, or the intermediate axis perpendicular to the longest axis.

[1] 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.

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

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 inFigure 1.

The 2012 sampling was conducted from the 24th till the 27th of September during which the average daily discharge in the Nechako River at Vanderhoof was about 82 m^3/s (based on preliminary WSC data at the 08JC001 gauge) and water temperatures ranged from 12 to 15^oC. In comparison, during the 2012 sampling program the discharge was about 103 m^3/s and the water temperature varied between 9 and 11^oC.

As-built surveys were not completed following the placement of the substrate, so it is difficult to know the exact extent of the placed material. Map 2 and Map 3 illustrate the areas where substrate was intended to be placed.

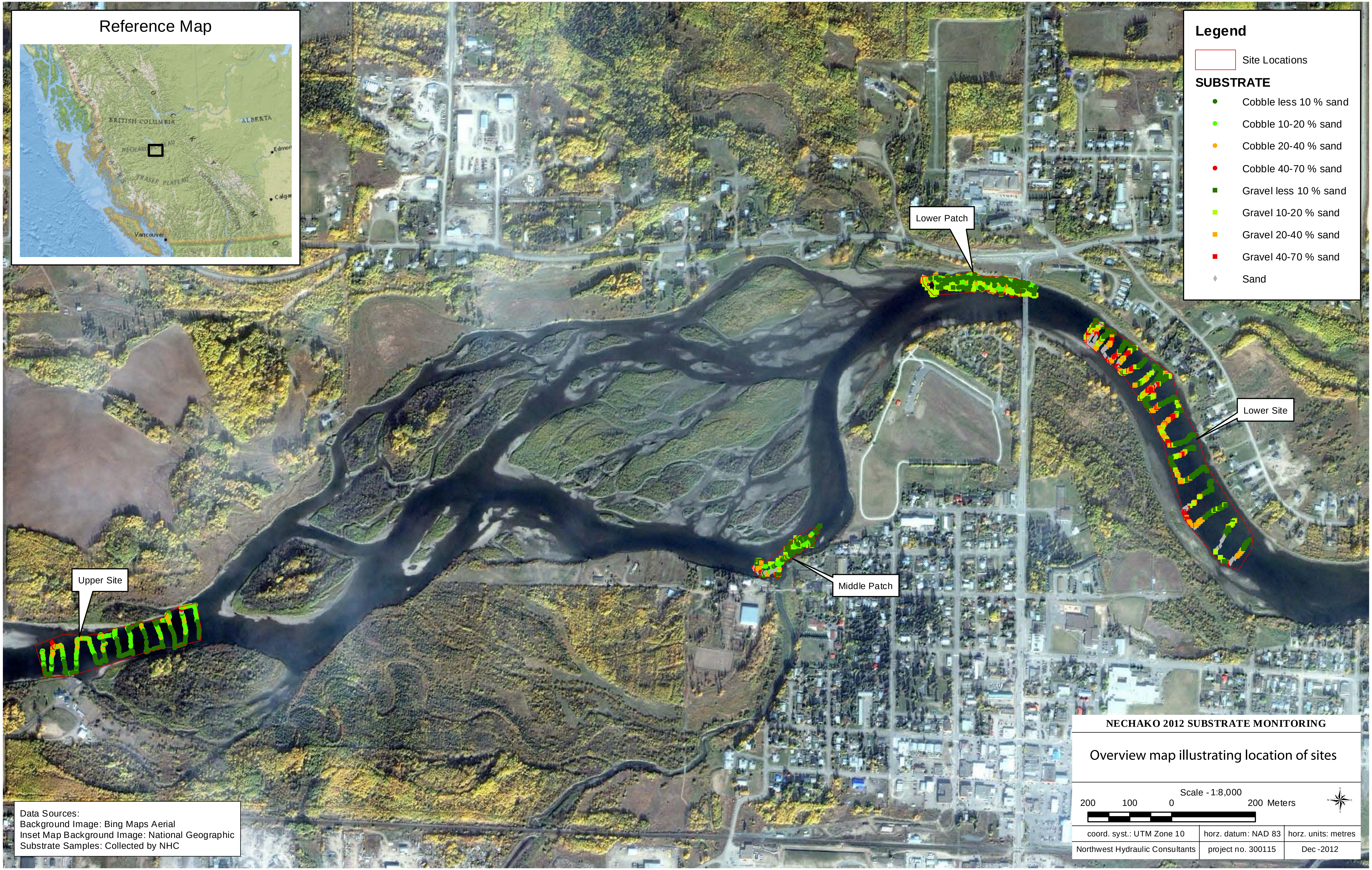

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Figure 1

3 METHODS

3.1 FREEZE CORE SAMPLING AND OBSERVATIONS

To collect samples of the substrate, a 2.5 or 3 m long metal pipe was hammered into the bed to a depth of about 0.3 meters and then liquid nitrogen was slowly poured into the pipe (Photo 1). While the liquid nitrogen was evaporating, heat was extracted out of the substrate around the core and as a result the substrate became frozen to the core (Photo 2). Once the liquid nitrogen quit evaporating the core was pulled from the bed and the sediment sample inspected. The initial sampling plan was to have 6 high quality cores from each of the sampling areas that were well distributed in space. Based on the 2011 sampling program it was estimated that five (5) liters of liquid nitrogen would be required per core. Initial testing in 2012 revealed that five (5) liters was insufficient to have confidence that the surface substrate would be recovered if it was full of fines. This was attributed to the warmer water temperatures during the 2012 sampling program. To improve the quality of the cores that were collected and to ensure fine sediment at the surface of the substrate would be collected if it was present, 10 liters of liquid nitrogen were used for the core. Since only 160 liters of liquid nitrogen was available for sampling, the total number of trustworthy cores was reduced to 13 (three from each sampling area except for the downstream most site). Given the reduced number of cores that could be collected, an attempt was made to use the cores to characterize the areas where fine sediment was not readily visible on the surface. Thus the sampling strategy was targeted towards areas that appeared more functional, rather than random or representative of the sampling areas on the whole.

Before starting to pour the liquid nitrogen the distance from the top of the core to the substrate surface was measured (the accuracy was about 2 cm but depends slightly on the size of stones on the bed). Then once the core was removed from the river, the distance from the top of the core to the top of the frozen sediment was measured. The distance from the top of the frozen sediment to the river substrate is a key metric; if fine sediment is found at the surface of the bed, the distances will be essentially the same. On account of measurement uncertainty, a difference of less than 2 cm was considered to indicate that fines were at the surface. In contrast, if the bed was free of fines, the water couldn't freeze around the larger stones due to the heat exchange that can occur in open pores, and as a result no sediment was returned to the surface. In these cases the distance between the elevation of the river bed surface and the point where sediment is retained on the core indicates the amount of sand free substrate.

Photo 1: **Liquid nitrogen being poured into the funnel that leads into a 20 mm diameter pipe that has an outlet 10-30 cm above the bottom of the core.**

Photo 2: **Freeze core # 9 from the Lower Site.**

3.2 Underwater Camera Observations

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. The images are subsequently reviewed and good quality images are saved. For the 2012 sampling program the camera mount was made more stable, and as a result the image quality was generally better than in 2011. The improved camera mount enabled a more detailed analysis of the infilling of the pore spaces to be completed with the 2012 images.

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. The training images and the percent sand associated with each image are shown in Appendix A. 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 through Map 4.

4 OBSERVATIONS

Summary data describing the core number, location and thickness of substrate that is free of fines are provided in Table 2. Only cores 8 through 20 provide an accurate estimate of the thickness of substrate that is free of fines. With the earlier cores less than 10 Liters of liquid nitrogen was used. A photo of each of the cores and the location the core was collected from is indicated on the respective sampling area maps (Map 1 through Map 4). In addition Appendix B contains a complete set of all the photos of the freeze cores. The reference frame for the surface is the mean elevation of the surface sediments rather than the bottom or top of the surface stones.

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 not 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.

Table 2: Freeze core sampling summary.

Core #	Location Description	Thickness of Substrate that may be clean (cm)	Comments
1	Lower Patch	13 cm	About 3L Liq. N used; not fully frozen
2	Lower Patch	15 cm	About 3L Liq. N used; not fully frozen
3	Lower Patch	unknown	About 3L Liq. N used; not fully frozen
4	Lower Patch	14 cm	5 L Liq. N used. Top bit not retrieved too warm, all fine material but surface was coarse and fines.
5	Lower Patch	25 cm	5 L Liq. N used, not fully frozen.
6	On edge of river in shallow fast flow just downstream of boat launch	25 cm	Small core tube used, doesn't pour well. Top not frozen.
7	In fast flowing water just off from boat launch	7 cm	
8	Lower Site	4 cm	Increased to 10 L for all subsequent cores
9	Lower Site	None	Good core
10	Lower Site	None	Moving sand at this location.
11	Lower Site	None	

12	Upper site	1 cm	
13	Upper site	3 cm	
14	Upper site	2 cm	Big stone on top was a surface stone
15	Middle Patch	8 cm	
16	Middle Patch	5 cm	
17	Middle Patch	6 cm	
18	Lower Patch	5 cm	
19	Lower Patch	5 cm	
20	Lower Patch	9 cm	

4.1 Upper Site

The upper site is considered to be important as it is a location where spawning has been assumed to occur historically and multiple pairs of fish were observed in 2004, 2006, 2007, 2008 and 2009 (Triton Consultants Ltd., 2004, 2007, 2010). It is also a site of relatively fast velocities during flood events (Northwest Hydraulic Consultants Ltd., 2008) and was identified as a potential substrate placement site. At the upstream end of the site there is a small sand/gravel bar on the left bank that tails into the site. Downstream the channel bifurcates and most of the flow goes down the right channel. During the site visit a number of Chinook redds were visible at the downstream end of the site.

Photo 3 and Photo 4 are example images of the river bed from the Upper Site. They both illustrate cobble substrate that is mostly clear of sand. In general the underwater photos show that the bed is predominantly covered by cobbles (Map 1) and that cobbles with less than 10 % sand is the dominant substrate type (Figure 3). Along the left side of the channel the bed has noticeably more fine sediment between the grains than along the right side of the channel. This is likely due to the hydraulics associated with the site (see Figure 2).

The downstream quarter of the river bed at this site was visibly more imbricated than the bed elsewhere. Imbrication occurs when flows are close to the threshold of motion as only grains in less stable locations move, and they tend to only move until they find a more stable location. This results in a stacking of the grains against each other, as this configuration is more stable. The resulting bed has a distinct appearance and is a good indication of near threshold transport conditions. The 2008 River2D modeling (Northwest Hydraulic Consultants Ltd., 2008) suggests shear stresses are on the order of 22 Pa during a flow of 460 m^3/s, which is similar to the peak discharge that occurred during 2011 and 2012 (see Section 4.5). Twenty-two (22) Pascals is below the critical shear stress for the bed, but close to threshold conditions.

The three freeze cores from the site show a gravel-cobble substrate with a limited amount of interstitial space (Map 1 and Table 2). Compared to the other sites, the native substrate is larger at this site and relatively close packed.

Overall the upper site appears to have areas of moderately high quality substrate that are stable and free of surface sand. Some sand moves through the site, but it is not retained within the surficial interstitial spaces. At depth sand fills the pore spaces and prevents eggs from being deposited at any great depth. Site conditions could only be improved by having a greater depth of open interstitial spaces, which could possibly be done by hydraulically loosening up the sediment and flushing fines. Such an approach would require further development and some testing.

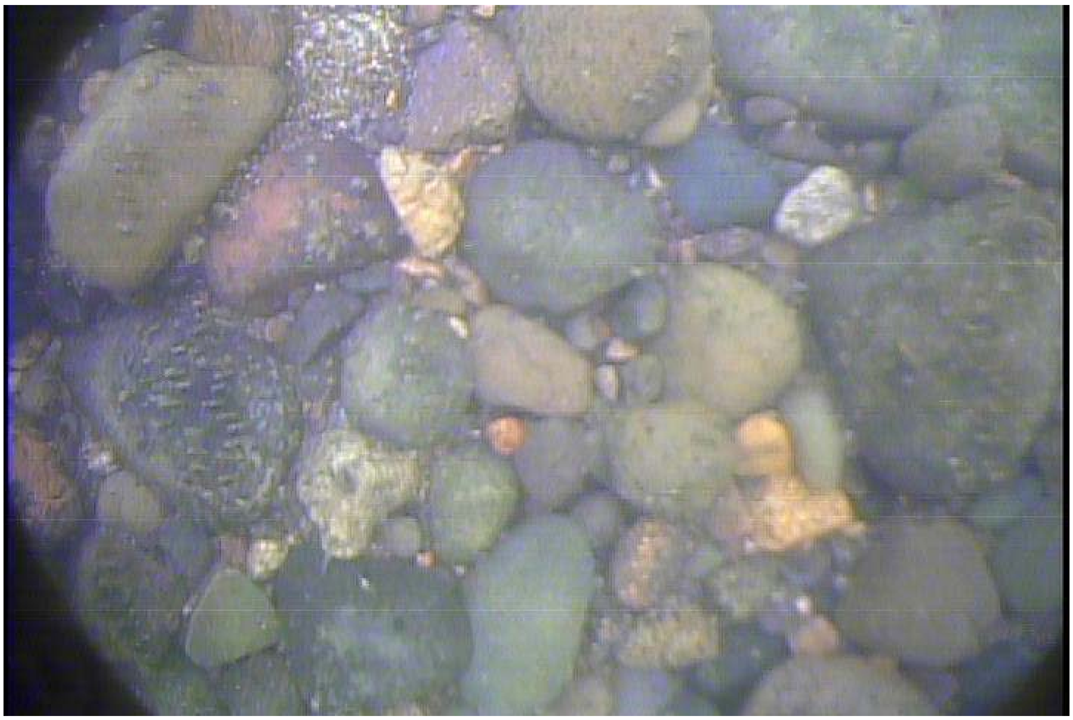

Photo 3: Underwater photo of substrate from Upper Site.

Photo 4: Underwater photo of substrate from Upper Site.

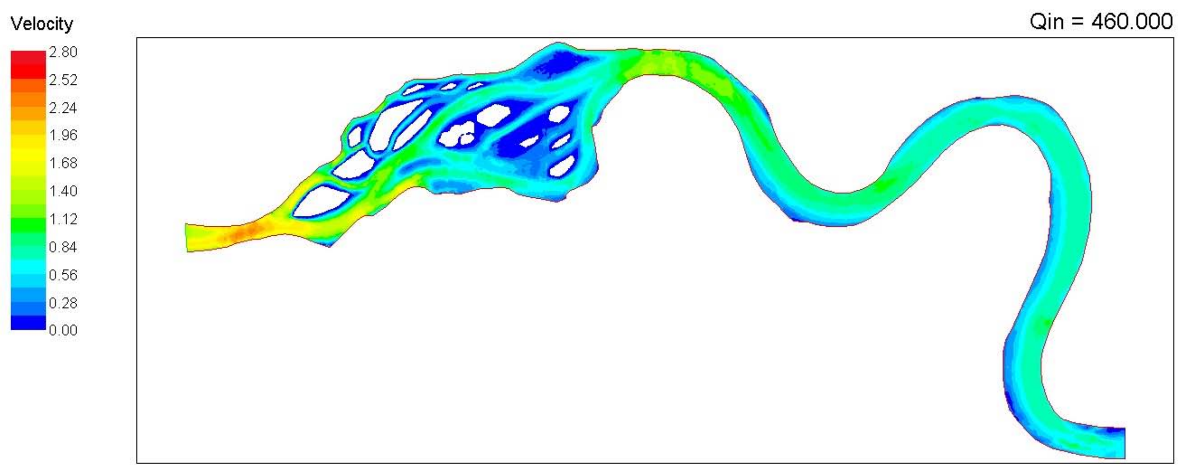

Figure 2: Figure illustrating velocity pattern at all four sites based on River2D model run (Northwest Hydraulic Consultants Ltd., 2008).

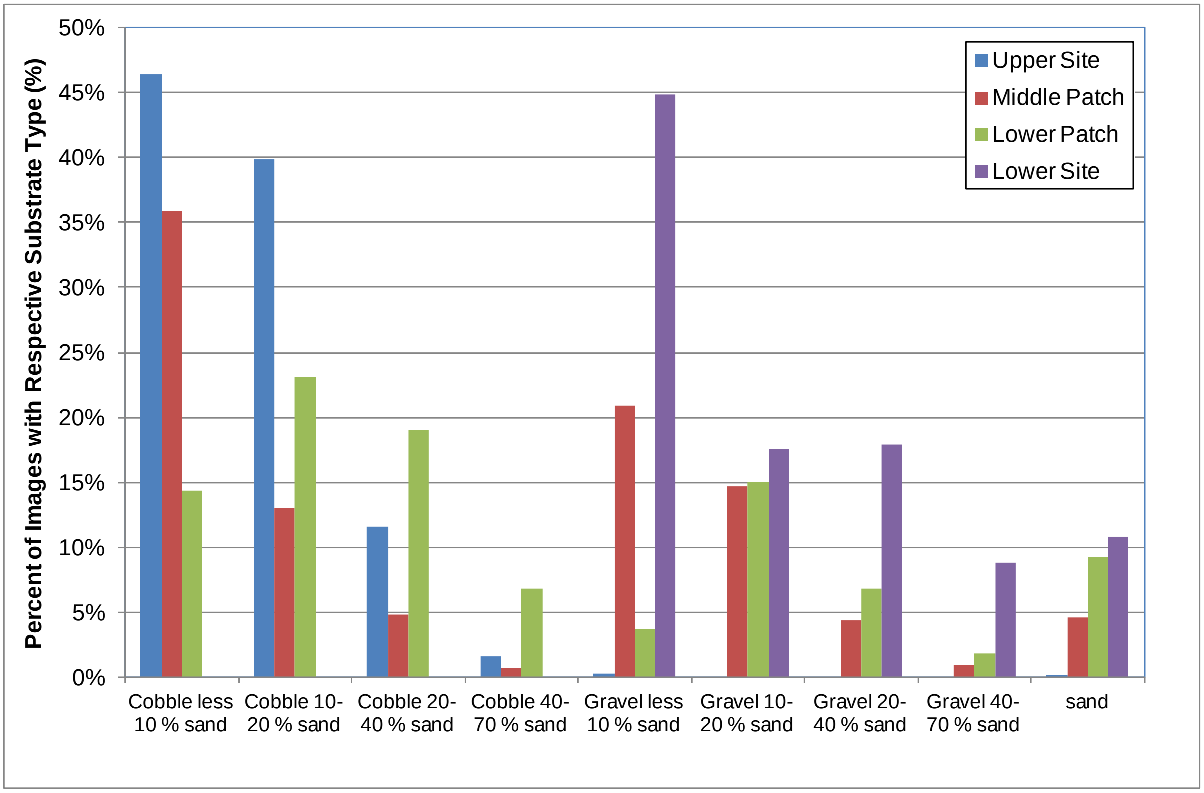

Figure 3: Substrate classification results for each site based on underwater images.

4.2 MIDDLE PATCH

The middle patch is located on the right bank side of an island complex just downstream of Stony Creek. The site is particularly deep at the upstream end, and shallows downstream. Filamentous algae covered tens of square meters of the upstream portion of the placed substrate (Photo 5). Adjacent to the placed substrate, strips of sand with ripples were visible indicating that sand is readily available and mobile at this site. A strip of sand leading into the site is indicated on the map showing the underwater photo data (Map 2).

Photo 6 and Photo 7 are two representative underwater photos from the Middle Patch. The middle patch is primarily cobbles (Figure 3); however, a fair percentage of the bed is also gravel. Most of the gravel and sand areas fall outside of the areas where substrate was placed. The larger cobbles appeared particularly stable at this site and many of them had a thick algae growth that did not appear to be abraded due to sediment transport (Photo 8).

The freeze cores were collected from areas with relatively little sand on the surface, and the freeze core data suggest that the cobble substrate may be clean of fines to a depth of 6-8 cm below the substrate (Table 2). The freeze cores show that the subsurface sediments (visible in images) are considerably finer than the placed cobble material (not recovered). This suggests that the placing of material at this site did increase the grain size of the surface sediments and has resulted in larger interstitial spaces. In general, the placed material is not being buried by gravel or in filled by sand; however, there are a few areas with a large amount of sand. These patches of sand are more common in lee environments created during the placement of the cobbles.

Overall the quality of the substrate at the Middle Patch appears to have degraded slightly since last year as there appeared to be more fine sediment in some areas. Nevertheless, there were still areas dominated by cobble substrate that were clear of fine sediment to some depth. This is particularly the case at the downstream end of the patch. There were no indications that the placed substrate moved, and it did not appear imbricated, which suggests that flood conditions during 2012 were well below the threshold of motion for the placed cobbles.

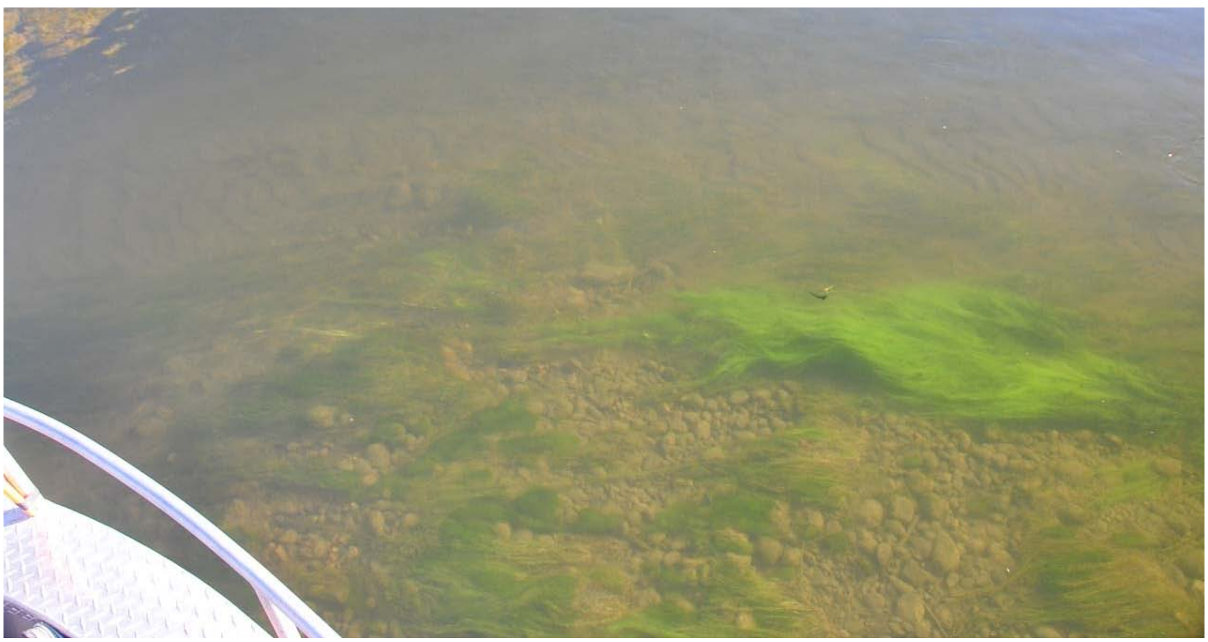

Photo 5: Filamentous algae growing on placed substrate. Note sand dunes moving along edge of placed substrate. Photo from upper stream end of Middle Patch.

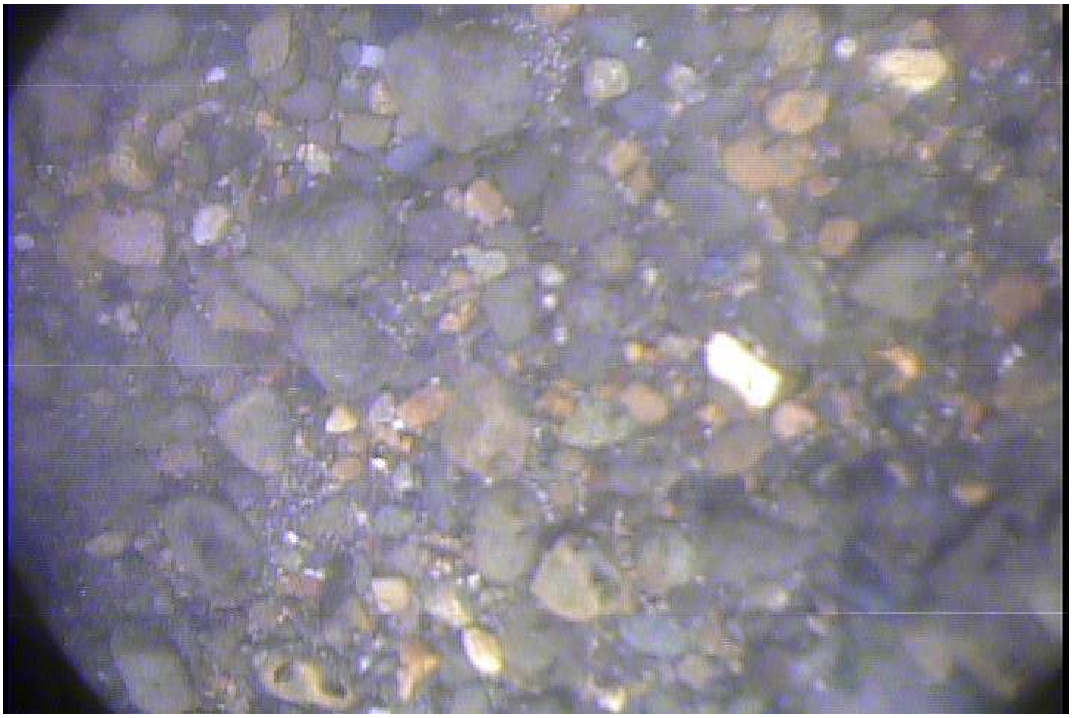

Photo 6: **Underwater photo of substrate from Middle Patch.**

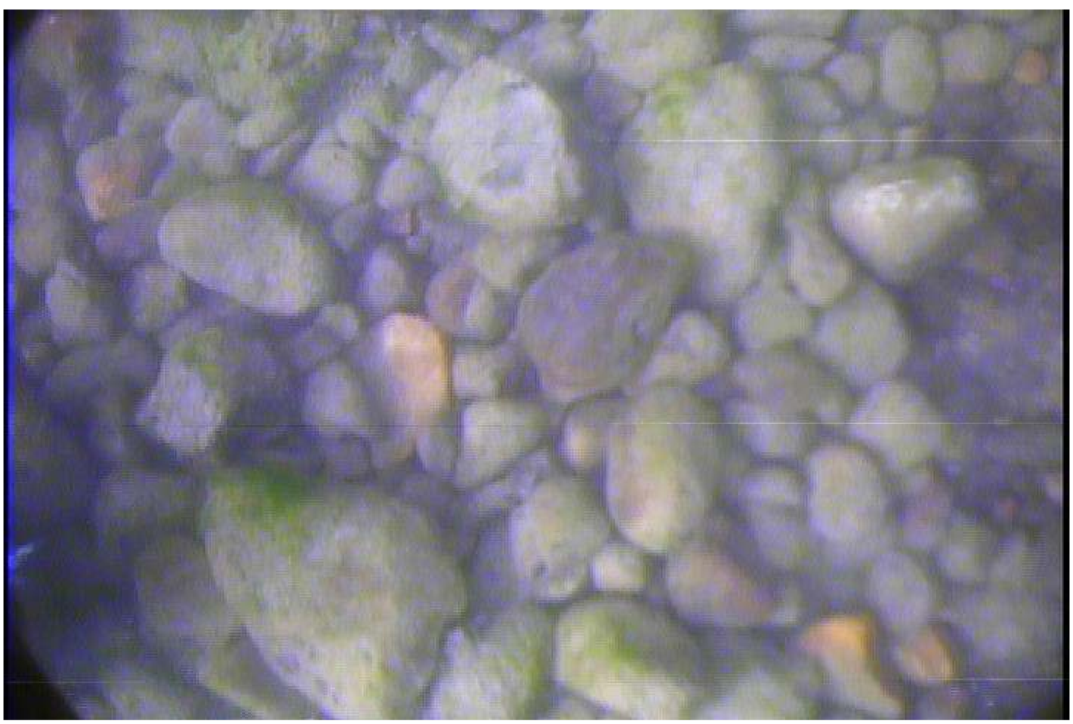

Photo 7: **Underwater photo of substrate from Middle Patch.**

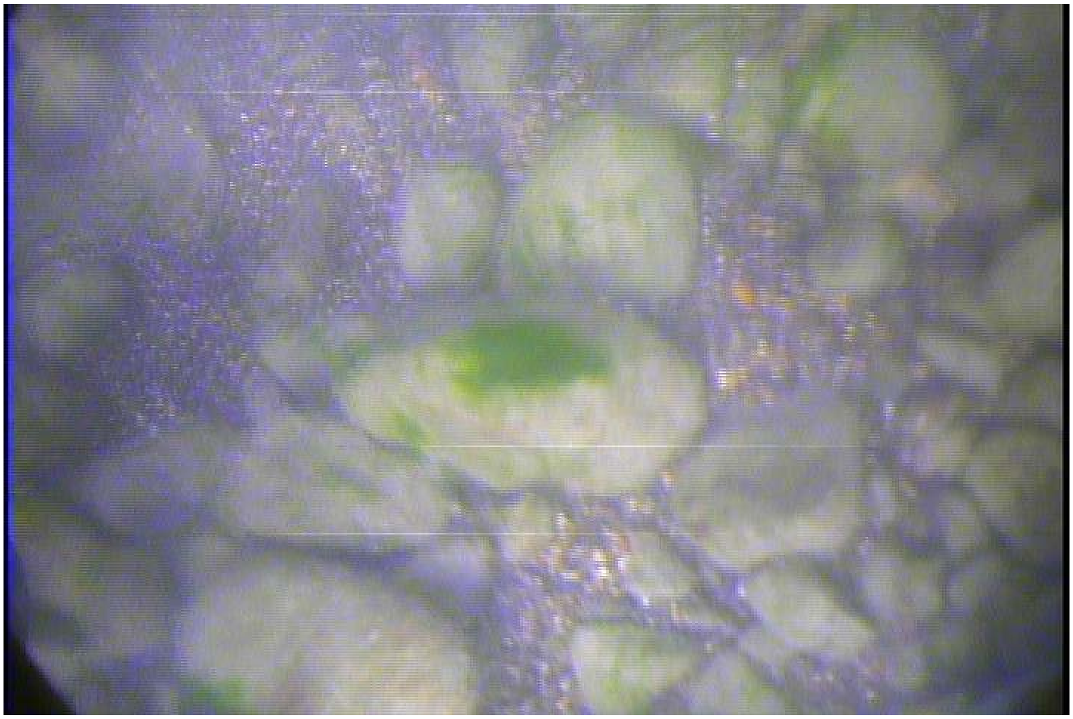

Photo 8: Underwater photo of cobble substrate from Middle Patch showing thick algae growth on larger stones and clean gravel/sand.

4.3 LOWER PATCH

The lower patch is located just downstream of the large island complex and Murray Creek confluence and just upstream of the Burrard Avenue Bridge. The placed substrate extends from moderate depths at the center of the channel to deeper areas along the right bank. In 2011 most of the sampling was done in the moderate depth areas. During the 2012 sampling trip much better coverage of the site was possible because of the lower water levels and improved camera mount. As a result more of the deeper areas were sampled. Site investigations confirm that placed substrate did not extend as far upstream as originally intended due to challenges associated with cabling the barges from shore. Photo 9 illustrates a small patch of placed substrate that was emergent during the site visit. At this location, and throughout the site, the placed substrate still maintained a hummocky topography characteristic of being dumped by an excavator. This was confirmed during a snorkel swim through the site and indicates that the placed substrate is not mobile during the floods conditions observed in 2011 and 2012. Previous River2D modelling suggests the area becomes backwatered during floods and as a result shear stresses are reduced. This greatly reduces the chances that the placed substrate will be moved at this site.

Photo 9: Placed substrate that is emerged out of the water is visible near the river bank while native gravels can be seen along the edge of the river bank. Photo from Lower Patch on left bank.

A visit to the outlet of Murray Creek indicates that it is not a significant source of medium to coarse sand (the material infilling the placed substrate). At the time of the visit Murray Creek was blocked off by a sand bar that has migrated down the Nechako River from the island group and appears incapable of moving significant quantities of bedload. The bed of Murray Creek at the confluence is predominantly silt and fine sand.

Photo 10: Outlet of Murray Creek blocked by a sand bar that has washed in from upstream.

Photo 11 and Photo 12 are two representative underwater photos from the Lower Patch that show high quality substrate that is free of fines. In contrast, Photo 13 shows a patch of placed substrate infilled with fine gravel and sand. During 2012 much more high quality substrate like that shown in Photo 11 and Photo 12 was observed compared to 2011. This observation suggests that either the 2011 sampling did not cover the areas of cleaner substrate (due to the deeper waters and lower quality underwater images) or fine substrate was flushed out by the 2012 freshet. . Map 3 illustrates the sampling results from the underwater images and shows that the deeper areas along the left bank commonly have less than 10 % sand while the shallow areas on the inside bend of the river were generally infilled with fines. This pattern is typical of river meanders as bedload often moves along the inside edge of bends, and the higher velocities on the outside of the bend keep mobile sediments moving.

Cores 18, 19 and 20 suggest that in areas where little to no sand is visible on the surface, the substrate may be clean of fines to a depth between 5 and 9 centimeters (TABLE 2). Like the Middle Patch, the freeze cores show that the subsurface sediments (visible in images) are considerably finer than the placed material (generally not recovered). This suggests that the placing of material at this site did increase the grain size of the surface sediments and has resulted in larger interstitial spaces. In general, the placed material is not being buried by gravel or in filled by sand.

During the field visit, a snorkel swim of this site was done to confirm the observations from the freeze cores and underwater images. Swimming enabled a closer, more detailed look at the substrate and better sense of the vertical variability of the bed. During the swim it was observed that the bed has retained a hummocky topography associated with the placement of the material. Little to no movement of the coarse substrate was observed, and a sledge hammer dropped in 2011 was recovered in 2012 at the same location it was dropped, confirming that the 2012 freshet did not alter the bed significantly. In lee areas behind hummocks created during the placement of the material it was also common for sand to accumulate. An initially surprising observation was that medium and coarse sand was mobile during the site visit and sand dunes could be seen moving under the Burrard Avenue Bridge. A review of the River2D model results confirms that high shear stresses are expected in the vicinity of the bridge during low flows as the backwater that establishes at high flows disappears. The field observations demonstrate that the movement of sand through these sites is not straightforward and does not necessarily follow the typical pattern of high transport rates during high flows.

Overall the quality of the substrate at the Lower Patch appears much better than anticipated based on the 2011 sampling program (Northwest Hydraulic Consultants Ltd., 2012). The substrate in the deeper areas along the outside of the bed is generally quite clean of fines and interstitial spaces where eggs may be deposited are plainly visible. There were no indications that the placed substrate moved, and the substrate did not appear imbricated, which suggests that flood conditions during 2012 were well below the threshold of motion for the placed cobbles.

Photo 11: Underwater photo of substrate from Lower Patch, note mussels in image.

Photo 12: **Underwater photo of substrate from Lower Patch.**

Photo 13: **Underwater photo of substrate from Lower Patch showing placed substrate infilled with fine gravel and sand.**

4.4 Lower Site

During the spring of 2012 a large number of eggs and some larvae were collected at the Lower Site and as a result the quality of the substrate at this site was of particular interest. The area included as part of the Lower Site investigations was considerably larger than the other sites (Figure 1). The Lower Site is relatively straight and has a fairly uniform cross section. Some small sand/gravel bars are present along the right side of the channel. The 2008 River2D modeling shows that the area becomes backwatered during floods and experiences considerably slower velocities than the upstream sites (Figure 2), as a result the substrate at the site is finer than at any of the other sites (Figure 3).

Photo 14 and Photo 15 are example images from the Lower Site. They both illustrate a coarse gravel substrate. Photo 14 illustrates a patch of substrate with a relatively thick fine sand/silt blanket indicative of a relatively inactive area. In contrast, Photo 15 lacks the silt layer and shows a patch of substrate with a number of mussels and reasonably dense macroinvertebrate growth. In general the underwater photos show that the bed is predominantly covered by gravel (Map 4) and that gravels with less than 10 % sand is the dominant substrate type (Figure 3). Of the four sampling areas, the Lower Site had the finest substrate and the most sand. The right side of the channel was generally finer and shallower and generally composed of gravel infilled with sand. In some areas, especially around Core 10, sand moving along the bed in strips could be seen (Photo 16). In the same area it was observed that there were lots of mussels on the right side of the channel where the substrate was more stable, compared to the left side of the channel where the bed was more mobile.

Freeze cores 8 through 11 demonstrate that the subsurface sediment is generally gravel with a large fraction of fines (Map 4 and Table 2). The oxidation visible in Core 8 suggests that the substrate at this site is relatively stable and relatively little vertical exchange of the bed material occurs with the gravel.

Overall the quality of the substrate at the Lower Site is considered to be marginal. There are areas of gravel that have little to no sand, but the gravel itself is small which limits the size and number of interstitial spaces. The relatively uniform bed topography is unlikely to create many opportunities for eggs to be deposited in low predation risk zones.

Photo 14: **Underwater photo of substrate from Lower Site.**

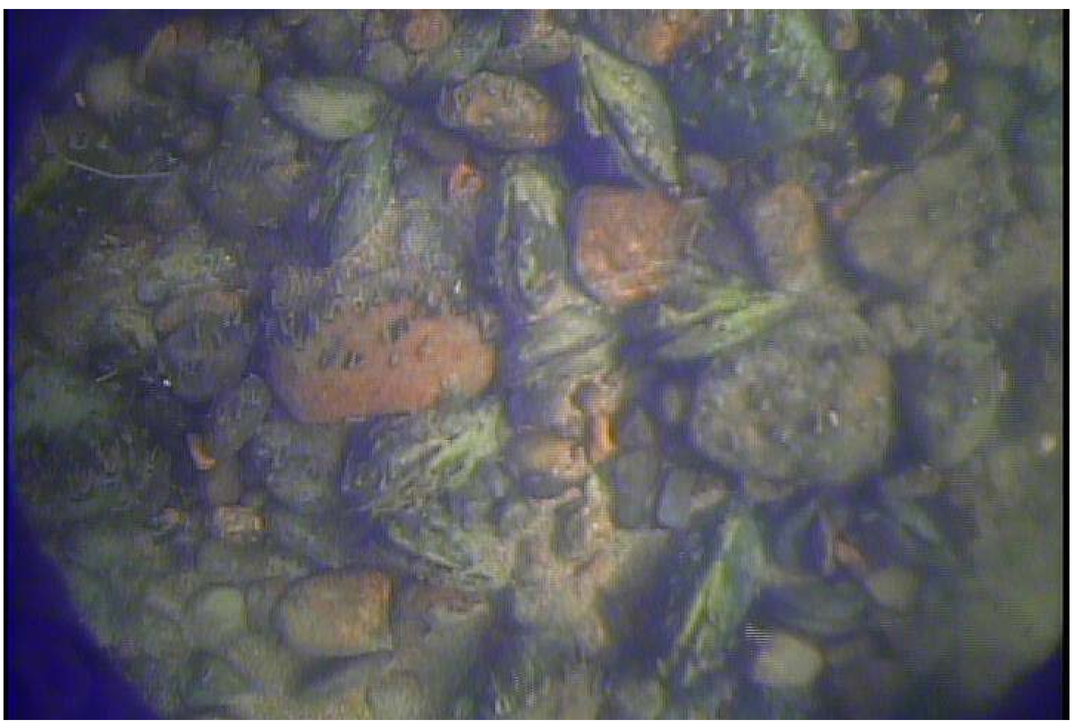

Photo 15: **Underwater photo of substrate from Lower Site.**

Photo 16: Photo of river bed at lower site illustrating strips of sand overtop of gravel.

4.5 2012 Freshet and Sediment Mobility

The 2011 freshet had a peak discharge about 500 m^3/s and lasted for about three months while the 2012 freshet peaked at 450 m^3/s and had sustained flows above 350 m^3/s for about 3 months (Figure 4). Based on daily data from 1962-2005, the 2011 flood peak had a return interval between 2 and 5 years and the 2012 freshet peaked at a 2 year return interval. In both cases the duration of the freshets were exceptionally long. Despite the relatively high flows the placed substrate did not move. Images of the substrate coupled with the 2008 River2D modelling (Northwest Hydraulic Consultants Ltd., 2008) suggest that the placed material will remain stable during most, if not all, flood events.

The lack of fines in the interstitial spaces between the cobbles at the three upper sites suggests that the 2011 and 2012 flood flows are capable of mobilizing sand from between the cobble grains. The presence of large sand bars and migrating sand dunes at the sites suggest that there is a significant supply of fine bedload.

On account of the backwater that establishes during high flows the location of high velocities and high shear stress changes as the flows change. At low flows, velocities and shear stresses are relatively high in the vicinity of the Burrard Avenue Bridge, while at high flows they are reduced (see Figure 4.1 and Figure 4.2 in Northwest Hydraulic Consultants Ltd., 2008). As a result the spatial distribution of high sand transport rates changes as the flow changes.

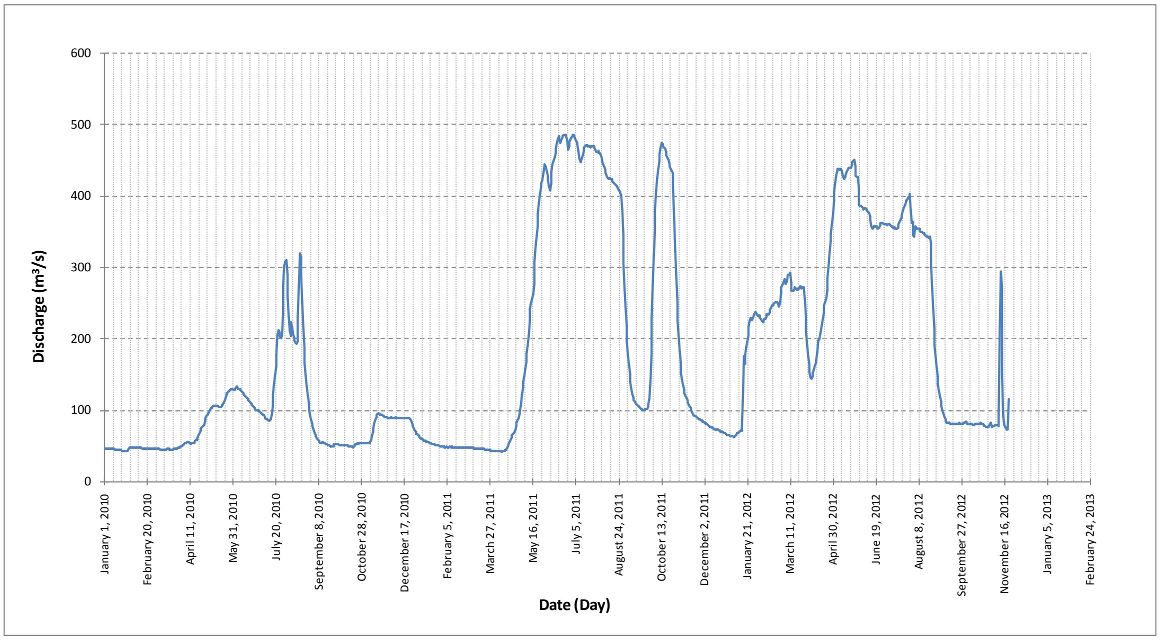

Figure 4: Discharge data from WSC 08JC001 gauge.

5 Conclusions and Recommendations

The freeze cores and underwater images demonstrate that good quality substrate exists at the Upper Site and the Middle and Lower Patches. The Lower Site has a distinct lack of cobble substrate and the substrate is in general of marginal quality - some interstitial spaces do exist between gravel grains, but these spaces are smaller than those found at the three upstream sites.

The site furthest upstream is the only one with naturally occurring cobble substrate and the substrate is quite imbricated. There does not appear to be sufficient energy to move these cobbles to the downstream areas. It is possible that hydraulically loosening up the cobbles and flushing some of the fines from the bed could improve the substrate quality at the Upper Site.

At the Middle Patch some infilling has occurred on the patches, and some filamentous algae is growing in other areas; nevertheless, the downstream portion of the patch remains free of fines and functional. The 2012 field work revealed that the Lower Patch is in better condition than expected. A large proportion of the placed substrate along the left bank side of the channel is free of fine sediment and the placed substrate remains functional. The right bank side of the placed material does have areas that were extensively infilled with fines. The placed material at both sites does not show any signs of being moved due to the floods.

The Lower Site is predominantly gravel and has more sand than any of the other sites and as such, it has the poorest substrate quality of any of the sites. Strips of sand could be seen moving over the bed which is partially a response to the increased shear stresses that occur during lower flows as the backwater effect disappears, and partially a result of the availability of sand in the system.

Based on the site investigations the quality of the substrate in the region could possibly be improved by hydraulically cleaning the Upper Site and placing cobble substrate at the Lower Site. At this time the two placed patches appear to be functioning reasonably well and remedial work does not appear warranted. A decision to place substrate at the Lower Site should only be done after considering all of the biological, geomorphic and potential flooding implications. Of particular interest is why the sturgeons appear to be spawning further downstream at present compared to the past, and if placing substrate at the Lower Site may result in a change in their spawning behaviour.

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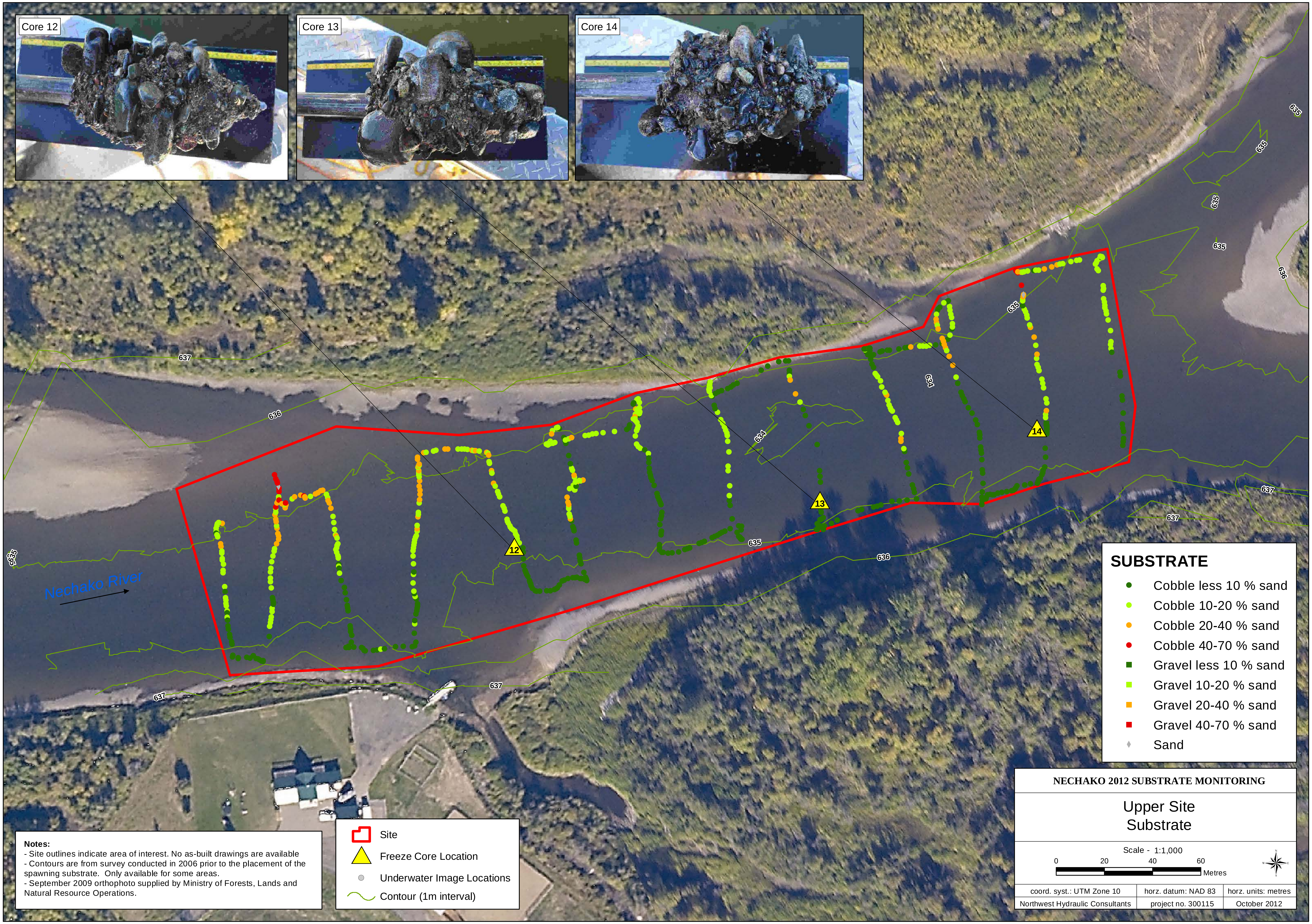
MAPS

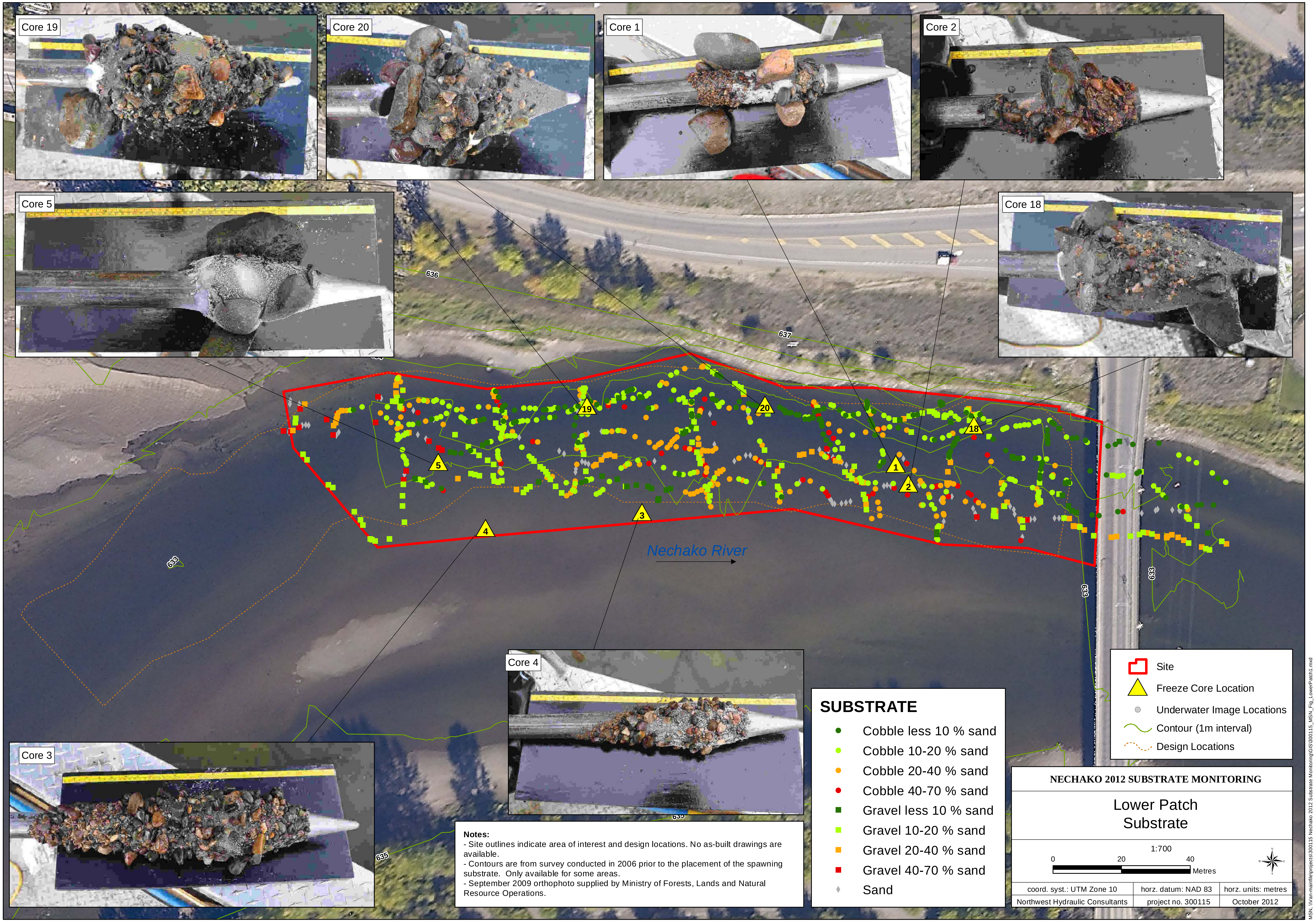


Core 12
Core 13
Core 14
Nechako River
12
13
14
637
636
635
634
SUBSTRATE
Cobble less 10 % sand
Cobble 10-20 % sand
Cobble 20-40 % sand
Cobble 40-70 % sand
Gravel less 10 % sand
Gravel 10-20 % sand
Gravel 20-40 % sand
Gravel 40-70 % sand
Sand
NECHAKO 2012 SUBSTRATE MONITORING
Upper Site
Substrate
Scale - 1:1,000
0 20 40 60
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
Northwest Hydraulic Consultants
project no. 300115
October 2012
Notes:
- Site outlines indicate area of interest. 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.
- September 2009 orthophoto supplied by Ministry of Forests, Lands and Natural Resource Operations.
Site
Freeze Core Location
Underwater Image Locations
Contour (1m interval)

Map 1

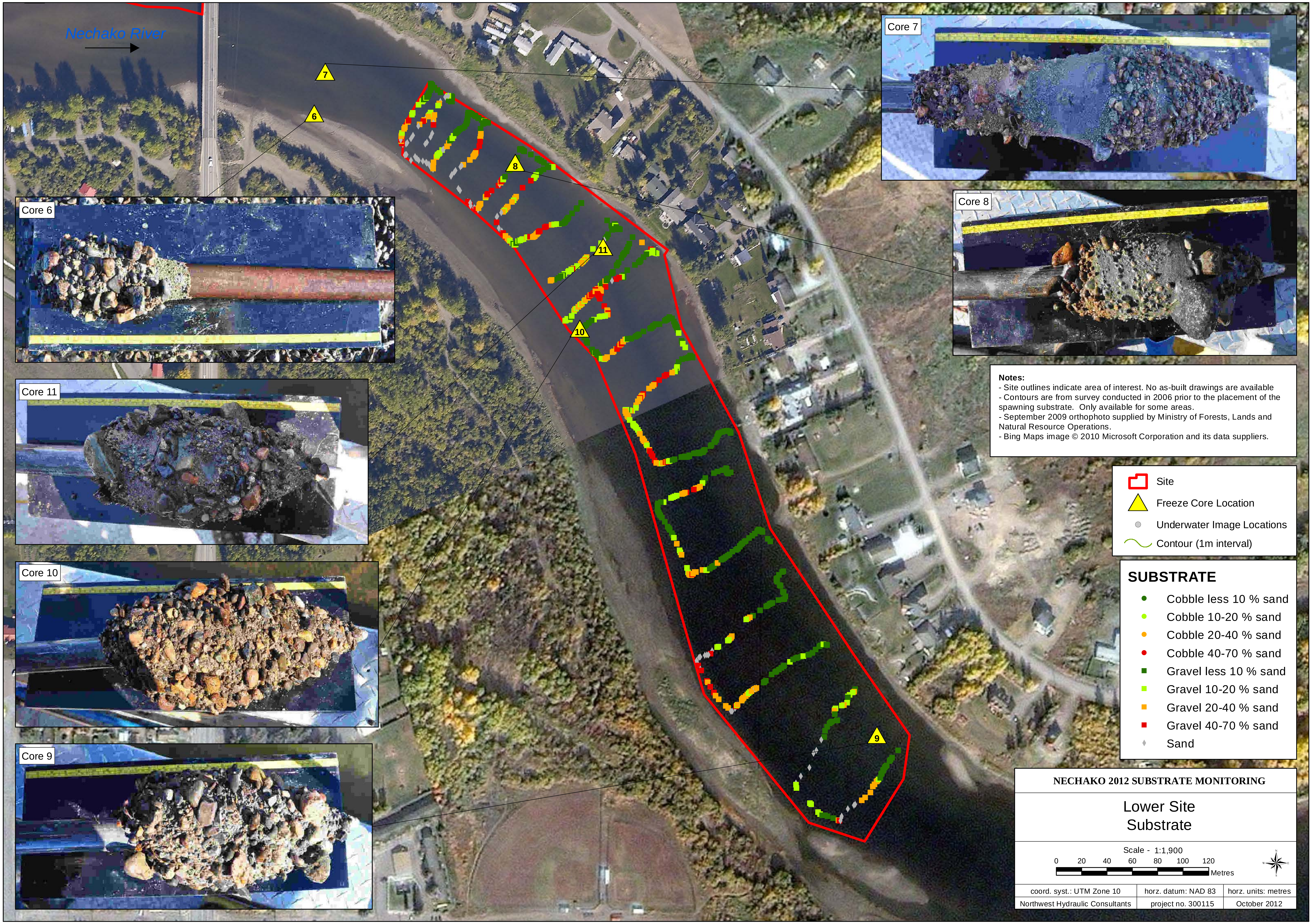

Core 15
Core 16
Core 17
Nechako River
15
16
17
SUBSTRATE
Cobble less 10 % sand
Cobble 10-20 % sand
Cobble 20-40 % sand
Cobble 40-70 % sand
Gravel less 10 % sand
Gravel 10-20 % sand
Gravel 20-40 % sand
Gravel 40-70 % sand
Sand
Site
Freeze Core Location
Underwater Image Locations
Contour (1m interval)
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.
- September 2009 orthophoto supplied by Ministry of Forests, Lands and Natural
NECHAKO 2012 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. 300115
October 2012

Map 2



Core 19
Core 20
Core 1
Core 2
Core 5
Core 18
Core 4
Core 3
19
20
18
5
1
2
3
4
636
637
633
635
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
Freeze Core Location
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.
- September 2009 orthophoto supplied by Ministry of Forests, Lands and Natural Resource Operations.
NECHAKO 2012 SUBSTRATE MONITORING
Lower Patch
Substrate
1:700
0
20
40
Metres
N
W
E
S
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
Northwest Hydraulic Consultants
project no. 300115
October 2012

Map 3


Nechako River
Core 7
Core 6
Core 8
Core 11
Core 10
Core 9
7
6
8
11
10
9
Notes:
- Site outlines indicate area of interest. 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.
- September 2009 orthophoto supplied by Ministry of Forests, Lands and Natural Resource Operations.
- Bing Maps image © 2010 Microsoft Corporation and its data suppliers.
Site
Freeze Core Location
Underwater Image Locations
Contour (1m interval)
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 2012 SUBSTRATE MONITORING
Lower Site
Substrate
Scale - 1:1,900
0 20 40 60 80 100 120
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
Northwest Hydraulic Consultants
project no. 300115
October 2012

Map 4

APPENDIX A

PERCENT SAND TRAINING IMAGES

The following images were used to guide the supervised classification of each of the underwater images. Visible areas of sand in each of the images were mapped and the total area covered by sand was then compared to the total area of the image covered by sediment. The percent of the bed covered by sand is indicated above each image.

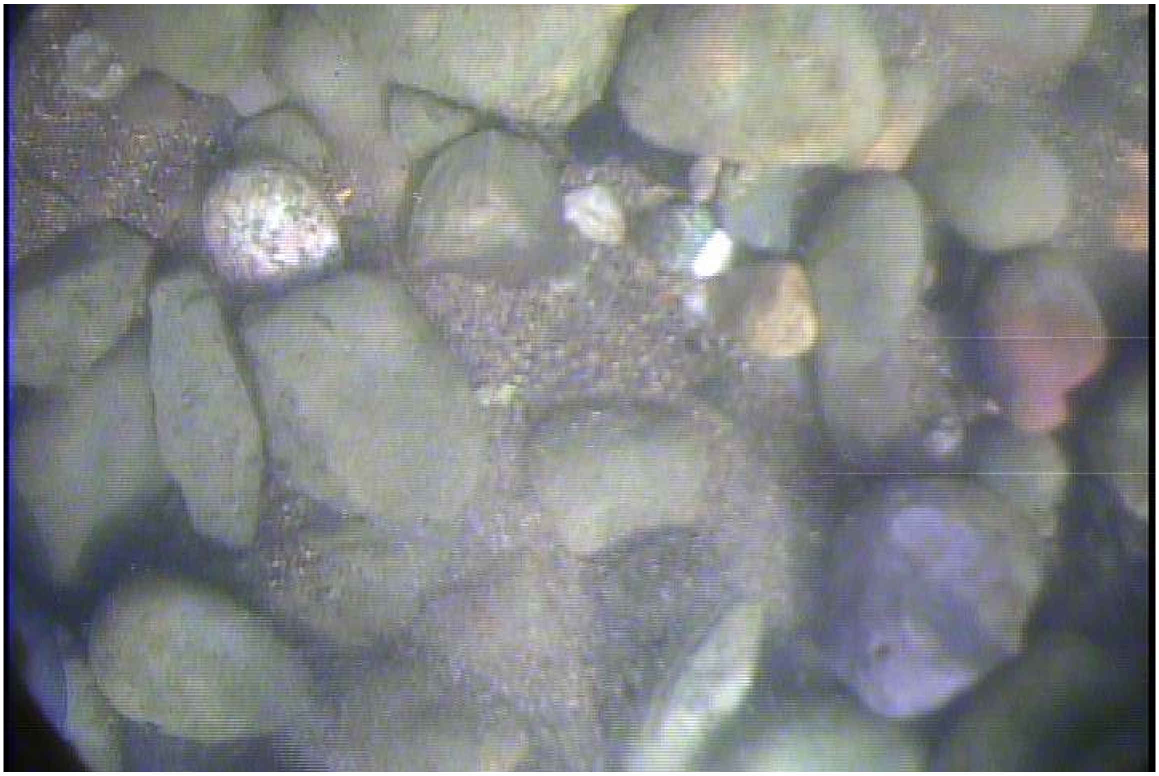
2% Sand (3431530892.556831.jpg)

17% Sand (3431619624.772826.jpg)

20% Sand (3431619638.022584.jpg)

nhc
northwest hydraulic consultants

25% Sand (3431619626.742939.jpg)



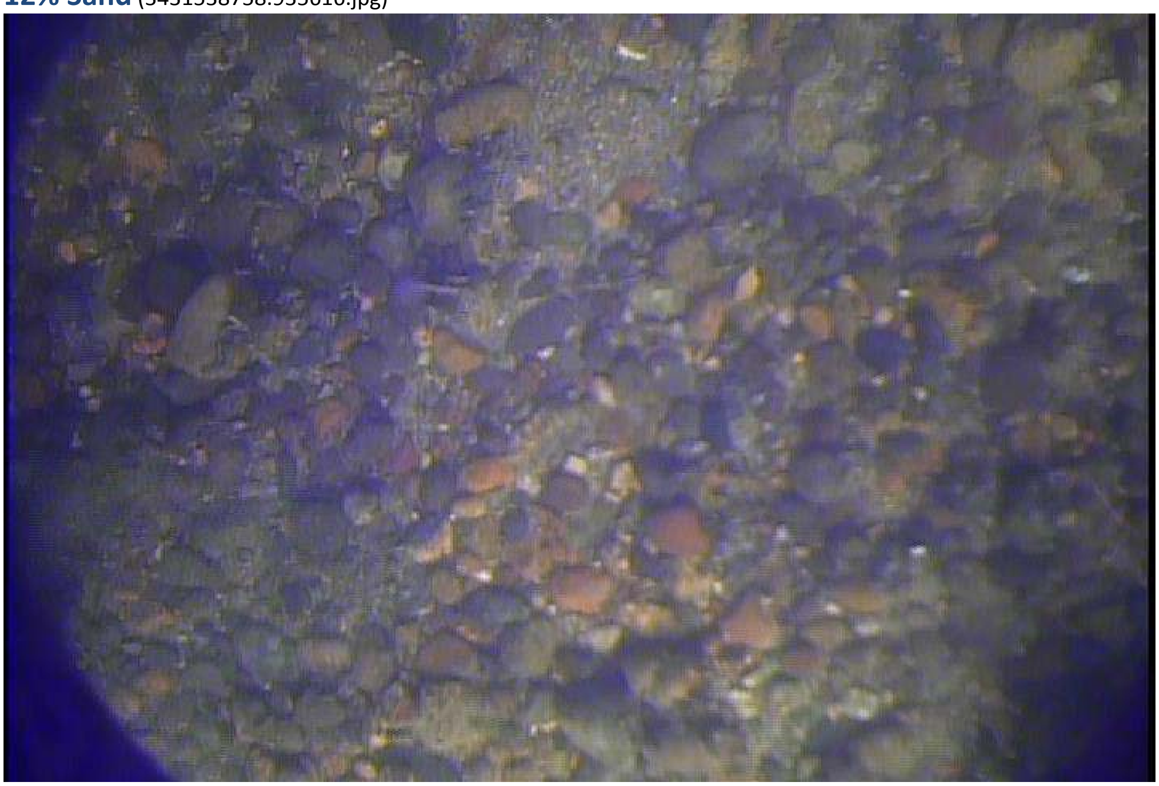
28% Sand (3431619630.173135.jpg)

38% Sand (3431365009.775072.jpg)

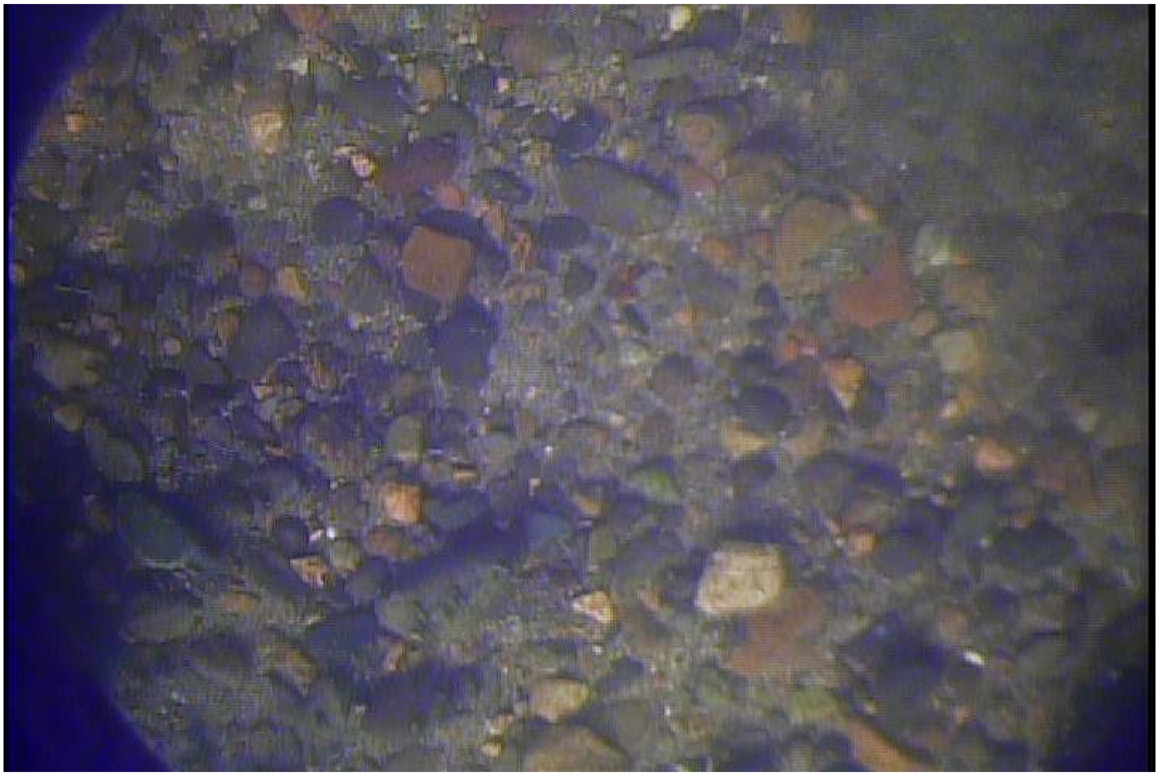
3% Sand (3431616433.260282.jpg)

10% Sand (3431616730.340274.jpg)

12% Sand (3431538758.935616.jpg)



14% Sand (3431539025.785879.jpg)



32% Sand (3431364920.743979.jpg)

75% Sand (3431364985.945709.jpg)

APPENDIX B

COMPLETE PHOTO COLLECTION OF FREEZE CORES

Photo 1: Core 1 (Lower Patch)

Photo 2: Core 2 (Lower Patch)

Photo 3: Core 3 (Lower Patch)

Photo 4: Core 4 (Lower Patch)

Photo 5: Core 5 (Lower Patch)

Photo 6: Core 6 (boat launch)

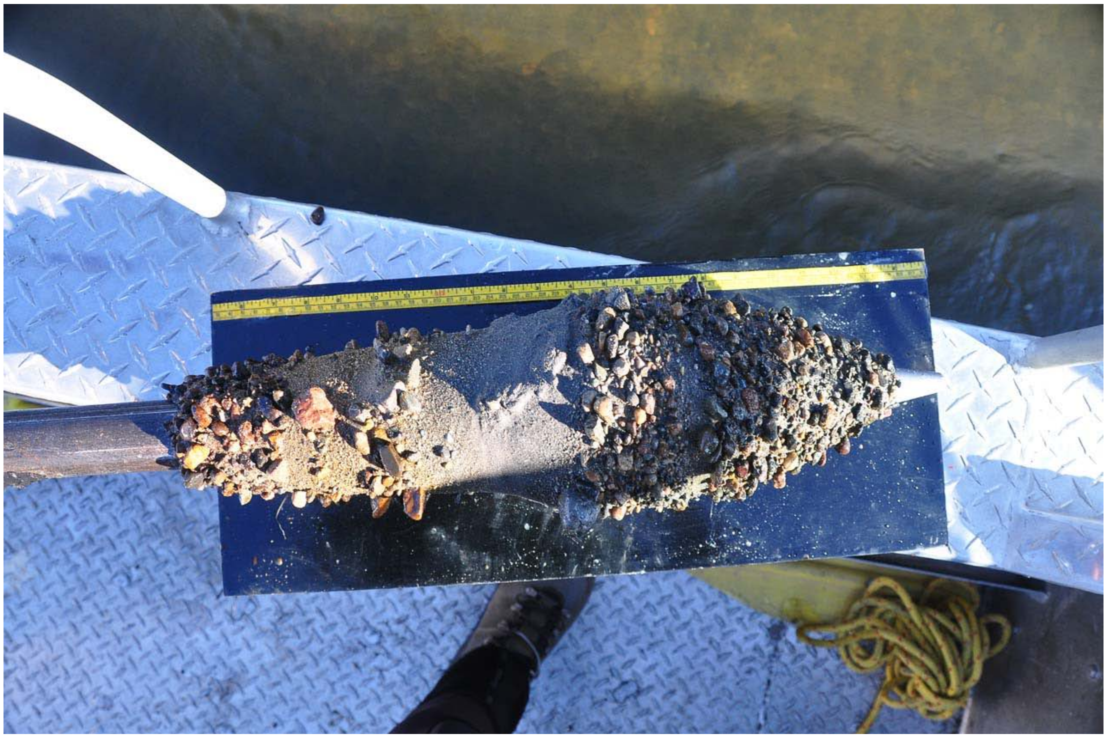


Photo 7: Core 7 (Boat Launch)

Photo 8: Core 7 (Boat Launch)

Photo 9: Core 8 (Lower Site)

Photo 10: Core 8 (Lower Site)

Photo 11: Core 8 (Lower Site)

Photo 12: Core 8 (Lower Site)

Photo 13: Core 9 (Lower Site)

Photo 14: Core 9 (Lower Site)

Photo 15: Core 9 (Lower Site)

Photo 16: Core 9 (Lower Site)

Photo 17: Core 10 (Lower Site)

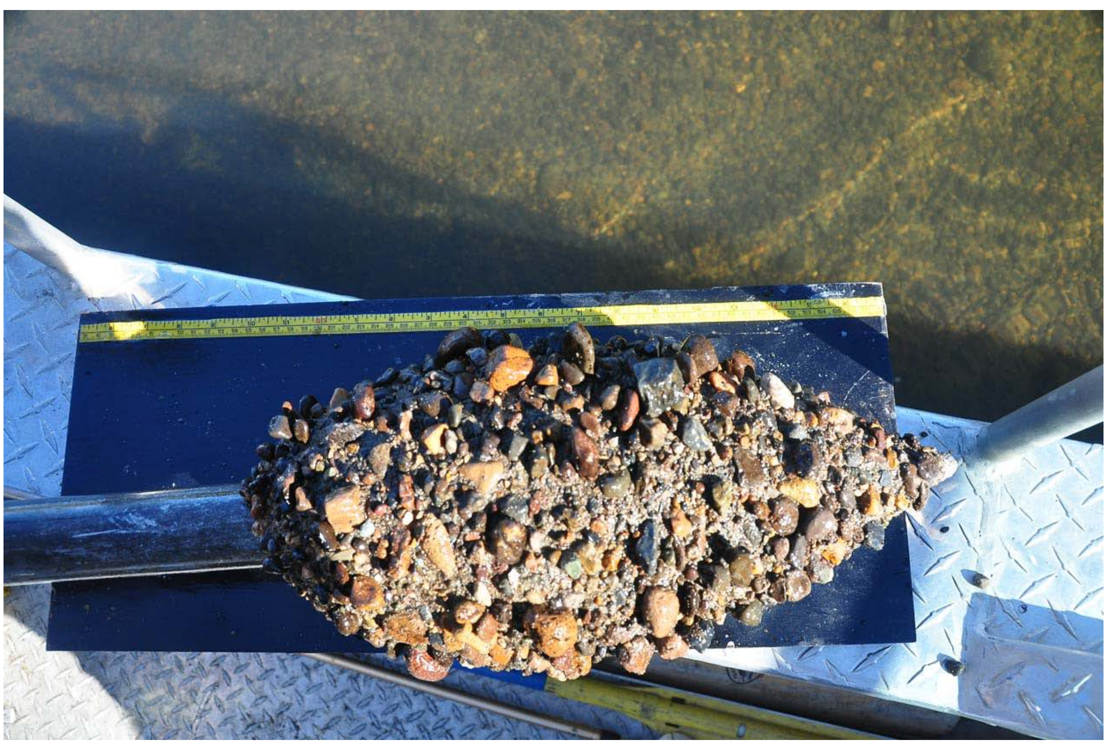


Photo 18: Core 10 (Lower Site)

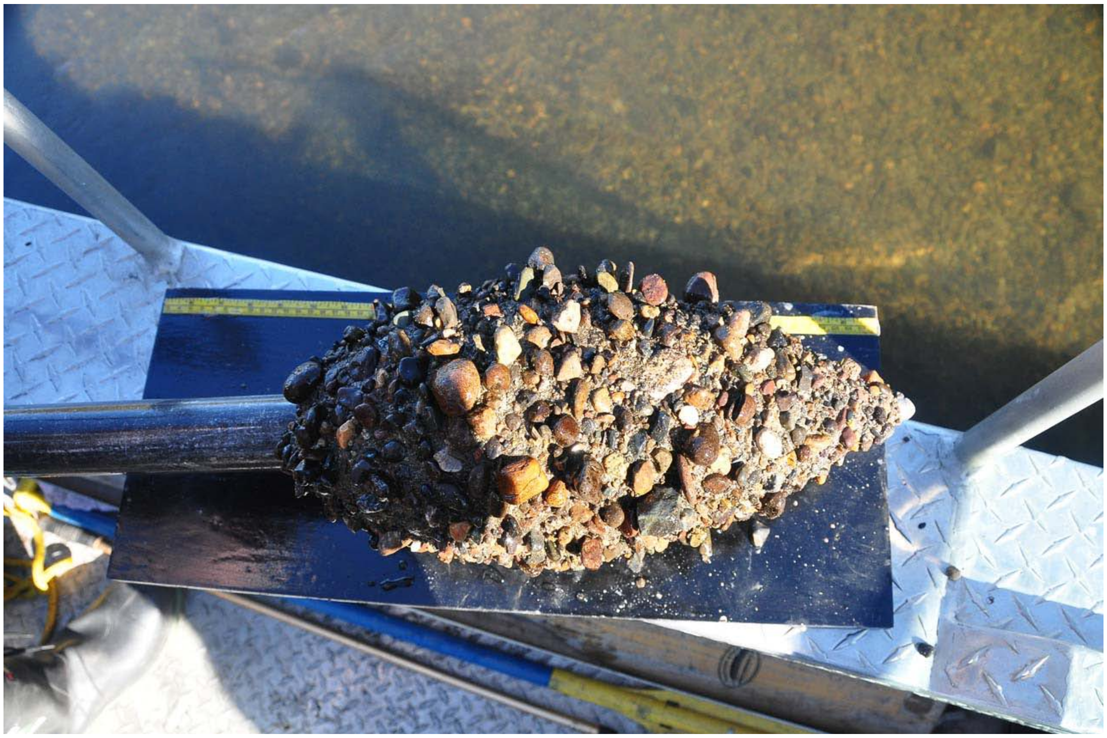


Photo 19: Core 10 (Lower Site)

Photo 20: Core 10 (Lower Site)

Photo 21: Core 11 (Lower Site)

Photo 22: Core 11 (Lower Site)

Photo 23: Core 11 (Lower Site)

Photo 24: Core 12 (Upper Site)

Photo 25: Core 12 (Upper Site)

Photo 26: Core 12 (Upper Site)

Photo 27: Core 12 (Upper Site)

Photo 28: Core 12 (Upper Site)

Photo 29: Core 13 (Upper Site)

Photo 30: Core 13 (Upper Site)

Photo 31: Core 13 (Upper Site)

Photo 32: Core 13 (Upper Site)

Photo 33: Core 13 (Upper Site)

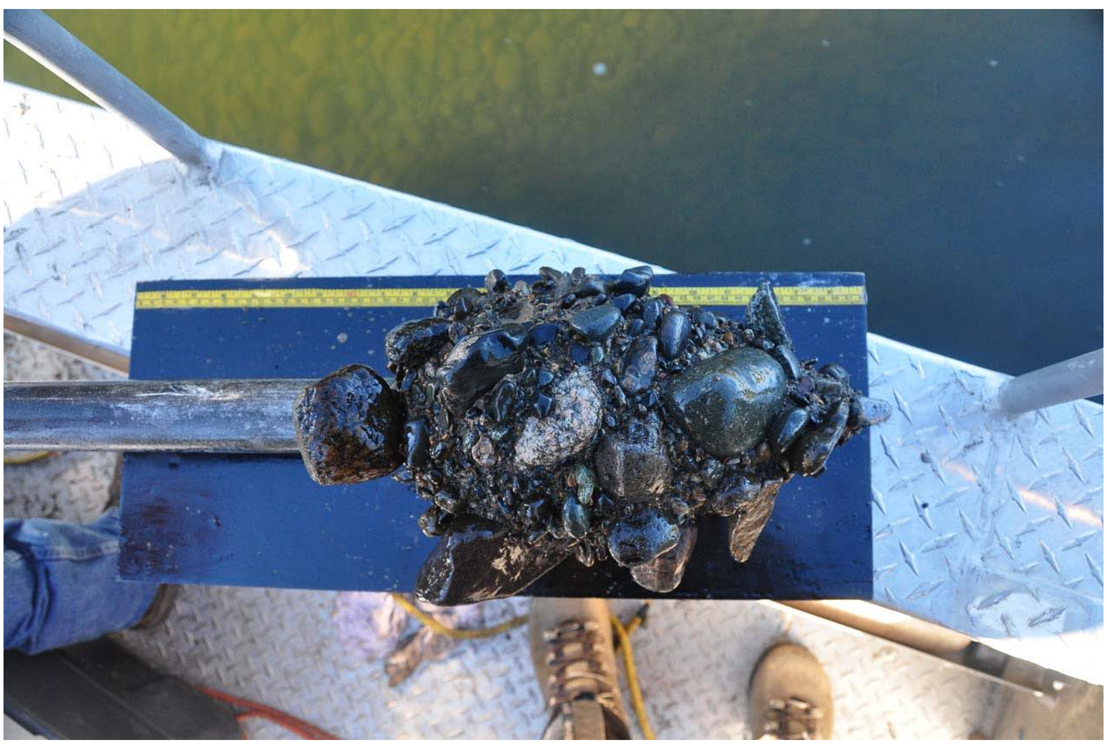


Photo 34: Core 14 (Upper Site)

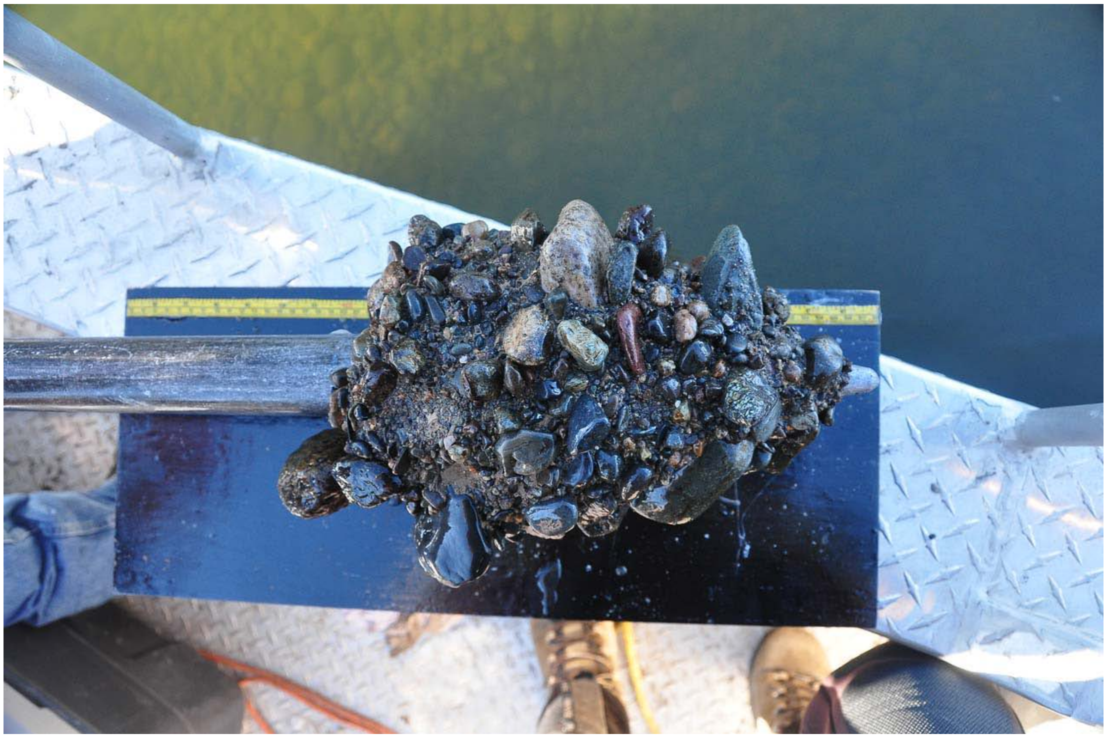


Photo 35: Core 14 (Upper Site)

Photo 36: Core 14 (Upper Site)

Photo 37: Core 14 (Upper Site)

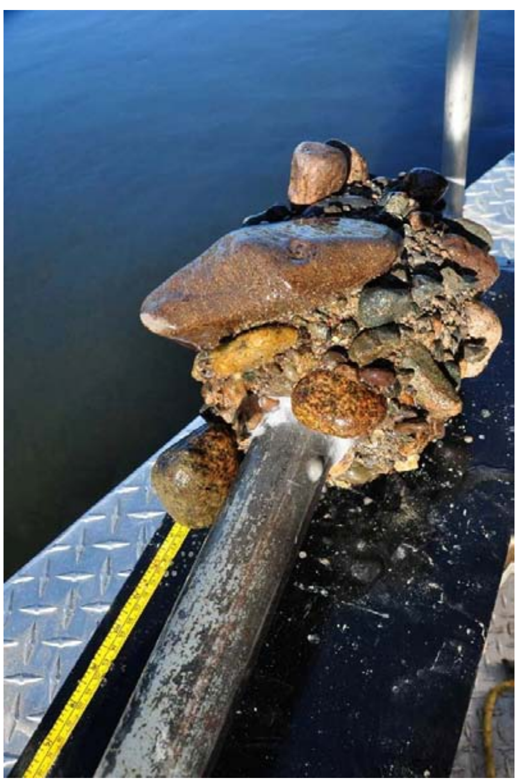


Photo 38: Core 14 (Upper Site)

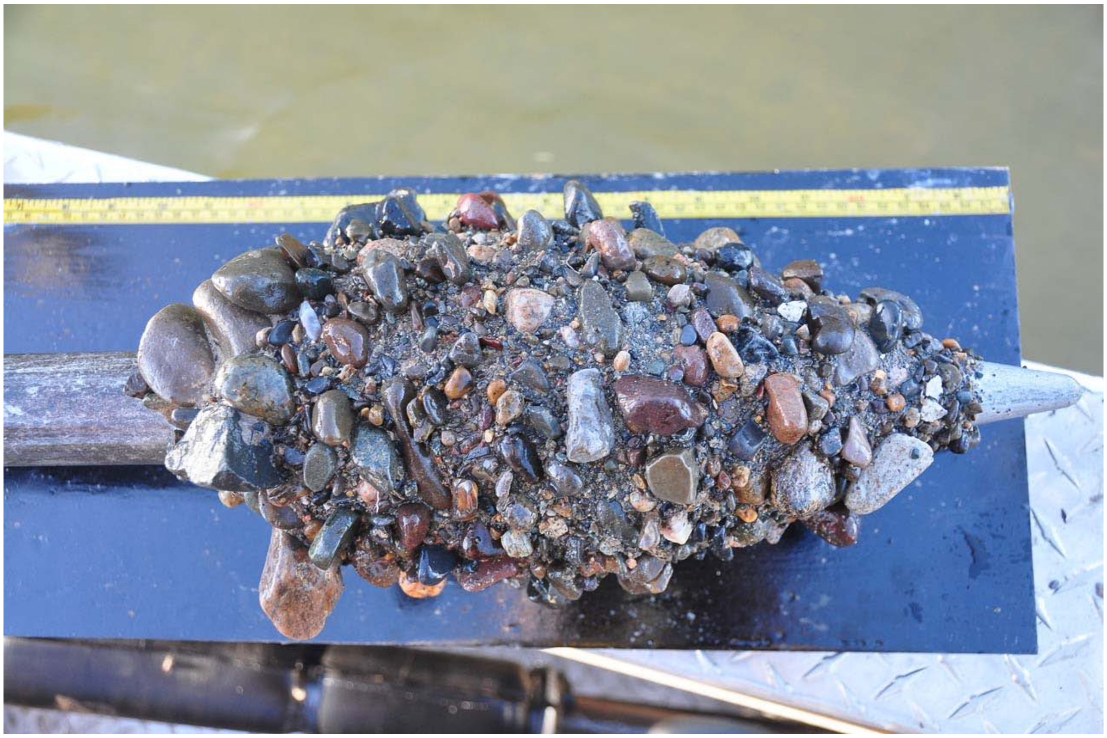


Photo 39: Core 15 (Middle Patch)

Photo 40: Core 15 (Middle Patch)

Photo 41: Core 15 (Middle Patch)

Photo 42: Core 15 (Middle Patch)

Photo 43: Core 15 (Middle Patch)

Photo 44: Core 15 (Middle Patch)

Photo 45: Core 15 (Middle Patch)

Photo 46: Core 16 (Middle Patch)

Photo 47: Core 16 (Middle Patch)

Photo 48: Core 16 (Middle Patch)

Photo 49: Core 16 (Middle Patch)

Photo 50: Core 16 (Middle Patch)

Photo 51: Core 16 (Middle Patch)

Photo 52: Core 16 (Middle Patch)

Photo 53: Core 16 (Middle Patch)

Photo 54: Core 16 (Middle Patch)

Photo 55: Core 17 (Middle Patch)

Photo 56: Core 17 (Middle Patch)

Photo 57: Core 17 (Middle Patch)

Photo 58: Core 17 (Middle Patch)

Photo 59: Core 17 (Middle Patch)

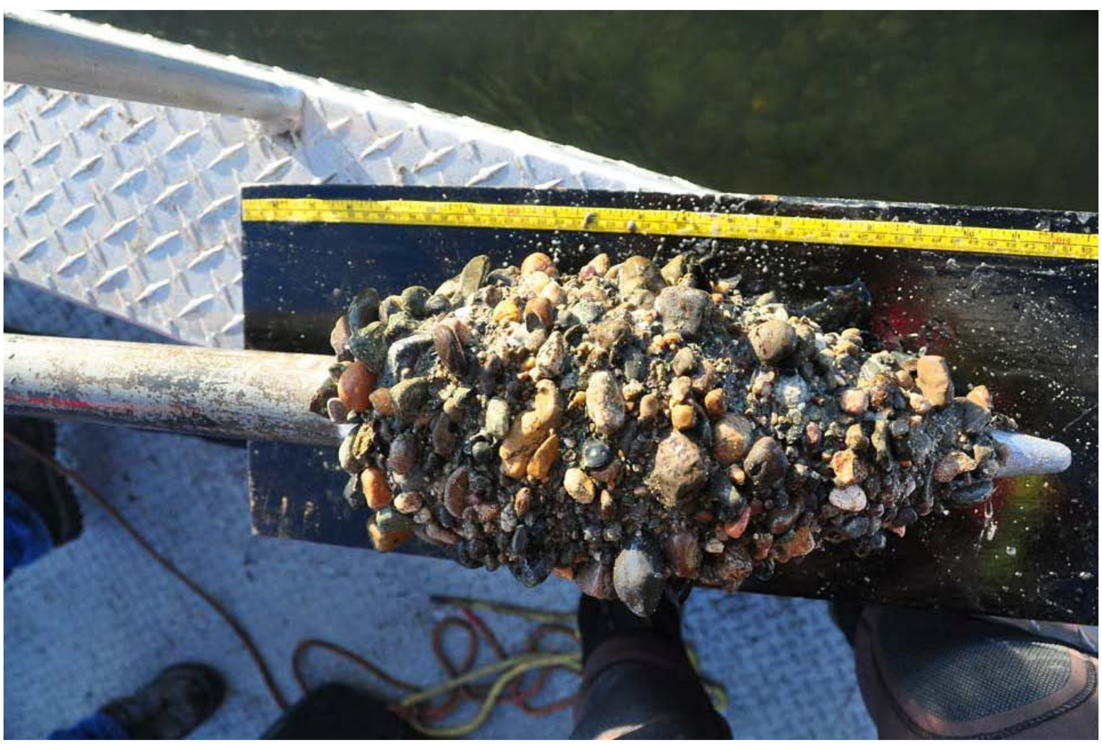


Photo 60: Core 17 (Middle Patch)

Photo 61: Core 18 (Lower Patch)

Photo 62: Core 18 (Lower Patch)

Photo 63: Core 18 (Lower Patch)

Photo 64: Core 18 (Lower Patch)

Photo 65: Core 18 (Lower Patch)

Photo 66: Core 18 (Lower Patch)

Photo 67: Core 18 (Lower Patch)

Photo 68: Core 19 (Lower Patch)

Photo 69: Core 19 (Lower Patch)

Photo 70: Core 19 (Lower Patch)

Photo 71: Core 19 (Lower Patch)

Photo 72: Core 19 (Lower Patch)

Photo 73: Core 19 (Lower Patch)

Photo 74: Core 19 (Lower Patch)

Photo 75: Core 19 (Lower Patch)

Photo 76: Core 20 (Lower Patch)

Photo 77: Core 20 (Lower Patch)

Photo 78: Core 20 (Lower Patch)

Photo 79: Core 20 (Lower Patch)

Photo 80: Core 20 (Lower Patch)

Photo 81: Core 20 (Lower Patch)

Photo 82: Core 20 (Lower Patch)

Photo 83: Core 20 (Lower Patch)