2016 Spawning Substrate Restoration on the Nechako River at Vanderhoof, BC

![BRITISH COLUMBIA]

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CERTIFICATION

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EXECUTIVE SUMMARY

The goal of the 2016 Spawning Substrate Restoration was to immediately improve the quality of white sturgeon spawning substrate and to determine the feasibly of using mechanical remediation as a restorative measure on the Nechako River. The instream work was done using a S2-3 Kaiser 4x4 Spyder Walking Excavator to sift and rake the substrate to dislodge fine sediment from within gravel interstices. The operation was conducted from April 6th to 7th, 2016 during a discharge of about 75 m^3/s. The relatively low discharge was ideal as local depths over the Lower Patch rarely exceeded the maximum working depth of 1.5 m. The early season timing of the work created operational issues associated with spring freshet preventing visibility of the substrate, but it also helped to minimize the magnitude of turbidity exceedances above background levels.

The operation effectively accessed approximately 7,260 m^2, or nearly 75% of the degraded Lower Patch spawning and incubation habitat. However, this overestimates the area specifically treated by the bucket due to inevitable gaps left between bucket placements. It is likely that most of the area accessed by the excavator was sufficiently disturbed to release infilled fines because the spacing between transects was approximately 15 m and it could reach approximately 8 m upstream and downstream of each transect. The remedial work was completed in about 10 hours of machine time.

Turbidity, suspended sediment and bedload transport were monitored at several locations throughout the remedial work period. The mean turbidity recorded directly downstream of the instream work was similar to ambient Nechako turbidity being logged by the Center Pier sensor located mid-channel. The maximum turbidity measured in the sediment plume, recorded when the excavator was working approximately 17 m directly upstream from the sensor, reached 71.3 FNU or about 45 FNU higher than the background turbidity. When the excavator was around 150 m upstream from the sensor, maximum turbidity decreased to 55.9 FNU, or about 30 FNU above the background level. Fluctuations in peak turbidity were rapid, suggesting the turbidity plume caused by the excavator had a fairly localized and temporary impact on the surrounding and downstream turbidity level.

The highest suspended sediment concentrations were sampled immediately downstream of the excavator. The mean sediment concentration upstream of the operation was 21.1 mg/L, while the mean concentration downstream of the excavator and downstream of the Lower Patch were 157.6 mg/L and 32.8 mg/L, respectively. This trend in sediment concentration provides a good indication that the operation was effective in promoting the downstream transport of fine sediment. The efficacy of the sifting and raking technique that was used to dislodge infilled fines is further supported by the size class of suspended material, since it corresponds to sediment typically transported as bedload over the Lower Patch. However, the sediment concentration and grainsize decreased downstream due to the rapid settling of suspended material, emphasizing the need for the remedial work to progress in relatively small downstream increments.

Bedload transport upstream of the Lower Patch was fairly low and constant during the remedial work, averaging 8.4 g/m/s. These rates remain consistent with data collected in 2015 and continue to reflect the current description of reach-scale sediment dynamics. Bedload rates directly downstream of the excavator were surprisingly low. This is likely explained by the lag time needed for the sediment to reach the sampler. The efficacy of the instream work to displace infilled fines was supported by the highest bedload transport rates, ranging from 22.1 g/m/s to 29.4 g/m/s, that were sampled at the downstream end of the Lower Patch. Furthermore, samples collected after the operation indicate transport rates on the Lower Patch dropped once the instream work ceased, with samples returning transport rates of 0.0 g/m/s, 0.6 g/m/s and 0.0 g/m/s near locations that previously had rates of 23.7 g/m/s, 4.8 g/m/s and 4.9 g/m/s, respectively. Although this suggests the operation was effective at dislodging and transporting infilled fines away from the Lower Patch, it also suggests that incoming bedload is likely to re-settle into the restored interstitial voids; the longevity of treatments was not monitored during the operation.

The restoration effort in 2016 improved the quality of white sturgeon spawning substrate and provided valuable experience for future cleaning efforts. The operation highlighted the importance of periodically mobilizing the static cobble/gravel substrate of the Lower Patch to release infilled fines. While several restorative strategies may exist to achieve this, mechanical remediation proved to be an effective means.

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1   INTRODUCTION

As part of the ongoing Nechako White Sturgeon Recovery Initiative, poor quality spawning substrate was mechanically remediated in April of 2016. The instream work was conducted within a known white sturgeon (*Acipenser transmontanus*) spawning area located on the Nechako River near Vanderhoof, BC. The purpose of the operation was to rapidly improve the quality of spawning substrate, prior to the 2016 spawning season, and to determine the feasibly of using such an approach as a long-term restorative measure. The present report discusses monitoring results of the 2016 restoration effort and is intended to serve as a reference for the planning of future remedial work.

1.1   BACKGROUND

The availability of interstitial space within coarse gravel substrate is a key determinant of white sturgeon survival through early life stages. Interstitial refuge increases sturgeon survival by providing a low-energy environment that can be used by the yolk sac larvae until the onset of exogenous feeding. If the gravel substrate has been infilled or covered by sand, larvae cannot access pore spaces and are forced to drift pre-maturely, resulting in higher predation and decreased survival (Kock et al., 2006; McAdam, 2011; Bennett et al., 2007).

In the Nechako River system, the onset of flow regulation in 1952, combined with tributary avulsions in the late 1950's and in 1972, have contributed to increasing sedimentation of coarse substrate within the critically important white sturgeon spawning reach located near Vanderhoof, BC (Figure 1). In conjunction with the change in substrate composition has been a reduction in juvenile sturgeon production to the point of chronic recruitment failure (McAdam et al., 2005; McAdam and NHC, 2003).

As part of the ongoing effort to resolve the recruitment failure within the Nechako white sturgeon population, the Ministry of Forest, Lands and Natural Resource Operations (MFLNRO) placed coarse cobble/gravel substrate at two sites within the critical spawning reach in May of 2011. These two sites are identified as the Middle Patch and Lower Patch on Figure 1. However, since 2011, significant sections of the spawning reach and particularly the Lower Patch spawning pad have infilled with medium to coarse sand (NHC, 2013; NHC, 2014; NHC, 2015; NHC, 2016). Because white sturgeon are a broadcast spawning fish that do not directly modify the substrate over which they spawn, a sediment cleaning plan was developed in 2015 to remove fine sediment that has infilled the cobble/gravel framework of the Lower Patch spawning pad (NHC, 2016).

Figure 1   Nechako River at Vanderhoof, BC. The 2016 Substrate Cleaning operation was conducted at the Lower Patch.

1.2   APPROACHES TO GRAVEL CLEANING

Mechanical and hydraulic cleaning of spawning gravel have been used to restore the quality of degraded substrate in artificial spawning channels and within natural river channels for a variety of fish species. For salmonids, the removal of infilled sediment and associated increase of inter-gravel flow has shown to increase dissolved oxygen delivery, metabolic water removal and egg-to-fry survival within the redd. In constructed spawning channels, constructed first by the IPSFC (International Pacific Salmon Fisheries Commission) and later through Fisheries and Oceans Canada Salmonid Enhancement Program (SEP), gravel cleaning was required to sustain high egg-to-fry survival and enhance recruitment to support fisheries.

Gravel cleaning techniques that have been used previously at salmon spawning channels include:

1. Gravel replacement: Removing the sediment-laden spawning gravels and replacing them with clean re-screened and graded gravel. This was an equipment-intensive technique that required additional gravel to be provided due to losses in handling. Often gravels were stored, re-screened and stockpiled for future use.

2. Air/Water Cleaner: Utilizing a specially constructed air/water cleaner (first designed by IPSFC Engineers) to dislodge sediments from the gravel and flush them downstream. The rake-like apparatus only cleaned about 20-30 cm depth and repeated use led to coarsening on the spawning channels, or pumping of sediments from the base of the channel.

3. Qualicum Method: Using a large bulldozer to manipulate the gravel bed, the flows were used to flush the sediments out the gravel and downstream. This method proved to be one of the more cost and operational effective gravel cleaning procedures. The scarification and

turning of the gravels helped re-sort and even out the gradation, and the mechanical action broke up sediment and algal accumulations.

4. Riffle Sifter/Gravel Gertie: Developed at the University of Washington and used in natural rivers, the Gertie used a jetted stream of water to dislodge and flush sediments from the gravel. It concentrated the sediments and discharged them to land while recirculating the cleaning water. The device was slow and could not clean extensive areas such as spawning channels, and was limited by the depth of flow it could operate in.

Although developed for different applications, these methods all intend to loosen and remove fine sediments from the voids in graded gravels. Several operational issues to consider when choosing an appropriate sediment removal technique include removal efficiency, desired production rate, slurry and/or downstream sediment management, how access to the area will influence machine manoeuvrability, as well as the logistics and costs involved (Palermo et al., 2008).

1.3 NECHAKO 2016 SPAWNING SUBSTRATE RESTORATION

Given the site-specific context and goals of the Nechako Sediment Cleaning operation, mechanical remediation using an S2-3 Kaiser 4x4 Spyder Walking Excavator (Figure 2) was selected as the most effective and efficient restorative measure (NHC, 2016). This method, similar to the Qualicum method described above, uses the excavator to rake, scarify and sift the cobble bed using a large 1.5 m-wide toothed bucket (Figure 3). Reasons which led to the selection of this method included its efficiency in removing infilled fines from the surface and subsurface layer, high instream maneuverability, ability to work in relatively deep and fast-flowing water, ability to move over wide areas, ability to access the Lower Patch with low impact and its lower cost and higher productivity relative to hydraulic dredging methods. That said, one major drawback of this mechanical cleaning method is that fine sediment is not actually removed from the system but is suspended into the water column, transported and eventually deposited downstream. Given that the substrate downstream of the Lower Patch is already composed largely of sand and silt, the suspension and resettling of fines was considered to have negligible impact on the overall habitat quality and substrate composition downstream.

The remedial work scheduled for the Nechako in 2016 needed to be performed within a relatively short window in April; between ice-off and the onset of sturgeon movement towards the spawning reach in May. This operating window created potential complications because it coincides with spring freshet on the Nechako system and its tributaries, resulting in highly variable discharge, depth and turbidity. The excavator is limited to a maximum operating depth of approximately 1.5 m over a firm, coarse substrate. Thick sand/silt substrates decrease the operating depth to less than 1.5 m due to the stabilizing arms pushing into the soft sediment. Maximum water depth at the Lower Patch during previous years (spring of 2013 and 2014) was estimated at approximately 2.8 m in the deepest part of the channel during a discharge of about 150 m^3/s. Table 1 (NHC, 2016) was used as a general guideline of discharge levels during which the task could be performed, with a discharge of 150 m^3/s or less considered ideal for the operation and flow over 200 m^3/s considered problematic as depth would significantly restrict the area accessed by excavator.

Figure 2 **S2-3 Kaiser 4x4 Spyder Walking Excavator accessing the Lower Patch directly from the north bank.**

Figure 3 **Excavator with 1.5 m-wide toothed bucket raking and sifting the cobble/gravel bed at the Lower Patch (placed substrate seen along bank).**

Table 1   Estimated maximum depth at Lower Patch at various discharge.

Discharge (m³/s)	Maximum Depth at Lower Patch (m)
100	2.4
150	2.8
200	3.1
250	3.4
300	3.7

2   METHODS

2.1   MECHANICAL REMEDIATION OF THE LOWER PATCH

The S2-3 Kaiser 4x4 Spyder Walking Excavator was operated by Len Masson, owner of Nu Creek Developments Ltd. The excavator was mobilized in the town of Vanderhoof and then driven directly across the Burrard Ave. Bridge and down the north bank of the river to access the Lower Patch. The remediation work began at the upstream most extent of the Lower Patch and gradually progressed downstream (Figure 4). The excavator generally worked from the mid-channel towards the bank along transects spaced roughly equal to the excavator's reach. Transect locations were not pre-determined and relied on the operator's experience and visual aids placed along the bank. The operation began on April 6th, 2016 at approximately 11:45, and was completed by around 13:00 on April 7th, 2016.

To sift, rake and scarify the substrate, the excavator would use its bucket to repeatedly dig and shake-out the substrate, thereby bringing fine sediment into suspension and allowing the coarsest material to re-deposit in place. The excavator bucket was approximately 1.5 m in width by 1 m in length and could therefore treat roughly 1.5 m² of the bed per bucket placement. The operator maintained a relatively constant digging depth of approximately 30 cm, which he would increase if there was a lack of cobble/gravel in the bucket indicative of a very thick sand deposit overtop the placed substrate. This process was repeated until minimal fines were observed by the operator in the bucket, at which point the excavator would progress along the transect. A handheld Garmin GPS unit was used to track the excavator's movement because the machine was not equipped with any positioning device.

Although the primary focus of the cleaning operation was placed on the Lower Patch, an exploratory site located approximately 550 m downstream of the Burrard Ave. Bridge was also investigated on the afternoon of April 7th, 2016. The exploratory site was located at 10N 434201m E 5986675m N.

Figure 4   Excavator beginning the remedial work at the upstream extent of the Lower Patch.

2.2   MONITORING OF TURBIDITY

Turbidity was continuously monitored during the operation by two Analite® turbidity sensors positioned downstream of the Lower Patch. The first sensor, previously installed on the south side of the middle bridge pier (NHC, 2016), has been transmitting data continuously since October 20th, 2014. The second sensor was a standalone unit, deployed specifically to measure the turbidity of the sediment plume caused by the remedial work and to assess potential downstream impacts. This standalone unit was fixed to a cinder block roughly 20 cm above the river bed and oriented obliquely downstream to prevent fouling of the signal caused by the accumulation of debris on the sensor (Figure 5). It was positioned directly downstream of the area to be cleaned (Map 1) and was initialized on April 6th, 2016 at 12:09, roughly 15 minutes after the start of the instream works. On April 7th, this sensor was repositioned several meters towards the north bank according to the excavator's progress to capture the highest turbidity located directly in the sediment plume. The sensor continuously logged data until it was removed at 17:32 on April 8th, 2016, one day after the instream work had ceased.

Figure 5   Standalone turbidity sensor installed downstream of the remedial work.

2.3   SUSPENDED SEDIMENT SAMPLING

Suspended sediment was sampled from April 6th to April 8th, 2016. Samples were collected at three locations; the first being a fixed position upstream of the remedial work acting as control, the second being a spatially variable position located immediately downstream of the excavator and the third being another fixed position at the downstream extent of the Lower Patch next to the standalone turbidity sensor (Map 1). Samples were generally collected at about 30 minute intervals, resulting in the collection of 8 samples on April 6th, 9 samples on April 7th and 3 samples on April 8th, 2016 for a total of 20 suspended sediment samples.

Sampling was conducted from a boat provided by the Nechako White Sturgeon Conservation Center (NWSCC) using a D-74 depth integrated sampler lowered from a Bridge Crane to control the rate of descent (Figure 6). The D-74 sampler was used with a ¼" nozzle attachment and samples were collected with a target transit rate of 0.1 m/s. Samples were subsequently sieved at the UBC Geography lab.

Figure 6   Sampling suspended sediment with the D-74 sampler downstream of the excavator.

2.4   BEDLOAD SEDIMENT SAMPLING

Similar to the suspended sediment sampling design, bedload transport was sampled from April 6th to April 8th, 2016 at the same three locations; upstream of the operation, at the downstream end of the Lower Patch and immediately downstream of the excavator (Figure 7). The upstream sample site in this project spatially corresponds to Site LP 4 in previous sediment transport investigations (NHC, 2015; NHC, 2016). Samples were again collected about every 30 minutes, resulting in the collection of 6, 11 and 3 samples on April 6th, 7th and 8th, respectively.

Sampling was conducted from the NWSCC boat using a Helley-Smith sampler with a 76.2 mm wide opening and 0.125 mm mesh bag. Due to the low sediment transport rates initially sampled, nearly all samples were collected over a duration of 10 minutes. To deploy the sampler, the boat was held in place using an anchor and the sampler was slowly lowered onto the bed. The rope was left slack and monitored to ensure there was no risk of the sampler being dragged due to lateral boat movement. All bedload samples were sieved at the UBC Geography lab using ½ phi sieves. 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 in Table 2.

Figure 7   **Sampling bedload sediment transport directly downstream of excavator.**

Table 2   **Wentworth grain size scale**

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

3   RESULTS

3.1   SUBSTRATE CLEANING

The remedial work was conducted during a discharge of approximately 75 m^3/s, which corresponds to an ideally low water level (Table 1). As seen in Map 2 and Map 3, an area of approximately 7,260 m^2 was accessed by the excavator; this area translates to about 75% of the total Lower Patch area (9,885 m^2). The only area that was too deep to access was an approximately 15 m wide section located at the upstream extent of the Lower Patch. The dimensions of the area accessed by the machine are roughly 175 m long by 40 m wide, however, this overestimates the area specifically treated by the bucket due to inevitable gaps left between bucket placements. It remains reasonable to assume that the majority of the area accessed by the excavator was sufficiently mechanically disturbed, either by the tracks or the bucket, to release infilled fines because the spacing between transects was approximately 15 m and it had a reach of approximately 8 m upstream and downstream of each transect. The instream work was conducted over about 10 hours of operation time, until the excavator had reached the downstream extent of the lower Patch.

The restoration effort intentionally excluded the near-bank area along the northwestern extent of the spawning pad for two reasons; this area was located within an eddy that did not have sufficient downstream velocity to sort the substrate during the sifting process and the excessive thickness of fine sediment overtop the coarse substrate was enough to render remedial efforts ineffective. The only portion of the Lower Patch that the excavator could not access was along the very deepest part of the thalweg at the upper extent of the spawning pad (Map 3). Maximum local depth in this area reached just over 2 m, as was expected from preliminary estimations in Table 1.

The spatial extent of the restored area was determined using a combination of GPS track data and a bed topography survey conducted on April 9th, 2016. Although a GPS track from the excavator was intended to be logged during both days of operation, issues with the GPS unit on the first day prevented track data from being collected on April 6th, 2016. For this reason, the boat survey was necessary to fill in the missing track data for the upstream portion of the spawning pad. Fortunately, the restored area was easily delineated during the boat survey by using a depth sounder that clearly depicted the hummocky bed topography left by the excavator during the sifting process. Although the abruptness of the mounds and divots left by the excavator is expected to smoothen over time, it is likely that a generally hummocky bed topography will persist at this location since the cobble/gravel substrate is rarely, if ever, mobilized by the flow.

The substrate at the exploratory site, located approximately 550 m downstream of the Burrard Ave. Bridge along the south bank of the river, lacked a coarse size fraction and therefore did not warrant any further cleaning effort (Figure 8).

Figure 8 **Substrate at the exploratory site lacking a coarse size fraction.**

3.2 TURBIDITY

The background turbidity of the Nechako River during the remedial work period was relatively high compared to previous years. Seen in Figure 9, the turbidity pulse associated with freshet was of lesser magnitude in 2016 than in 2015, but was more prolonged. During the period spanning from April 1st to April 10th, the mean and maximum turbidity in 2015 was 17.8 FNU and 40.5 FNU respectively, while in 2016 the mean and maximum was 26.3 FNU and 45.1 FNU. It is important to note that during this period, the 2016 peak turbidity of 45.1 FNU was recorded on March 25th and was therefore unrelated to the instream operations.

Over the course of the instream work, the average turbidity measured by the standalone sensor installed directly downstream of the restoration site was 26.5 FNU, which is only slightly more than the average turbidity of 25.9 FNU measured by the Center Pier sensor during this time. This, along with the rapid spikes in peak turbidity seen in Figure 10, suggest that the sediment plume caused by the instream work had a localized and temporary impact on the surrounding and downstream turbidity level. That said, the turbidity spikes measured by the standalone sensor provide a useful estimate of peak turbidity directly within the narrow plume.

The maximum turbidity caused by the operation was 71.3 FNU, recorded at 11:47 on April 7th, 2016 (Figure 10). This timing corresponds to when the excavator was working approximately 17 m directly upstream from the sensor. Again, the localized impact of the sediment plume is reflected by the 35.5 FNU and 31.9 FNU recorded 5 minutes before and after the peak, respectively. The next highest turbidity levels recorded on April 7th reached 55.3 FNU and 60.7 FNU, although the 60.7 FNU measurement was recorded at 7:24 prior to the commencement of instream work that day. On the first day of operations, when the excavator was working at the upstream extent of the Lower Patch approximately 140 m upstream of the sensor, maximum turbidity ranged from 47.9 FNU to 55.9 FNU.
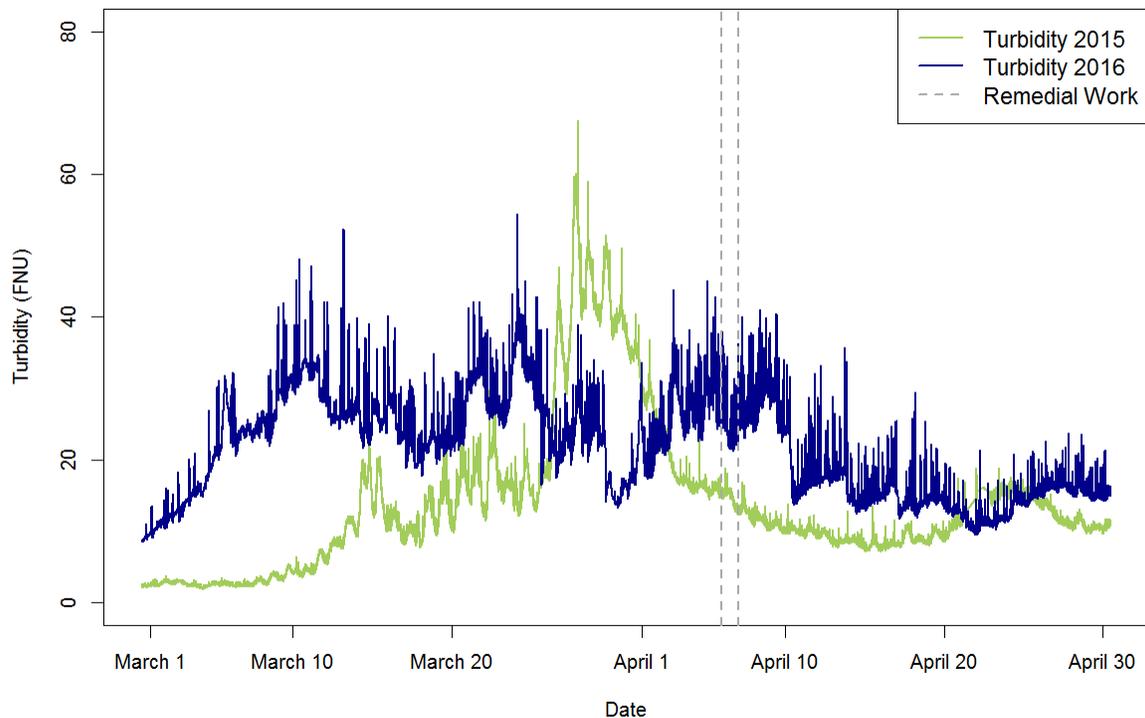

Figure 9   **Turbidity from the Center Pier sensor in 2015 and 2016.**
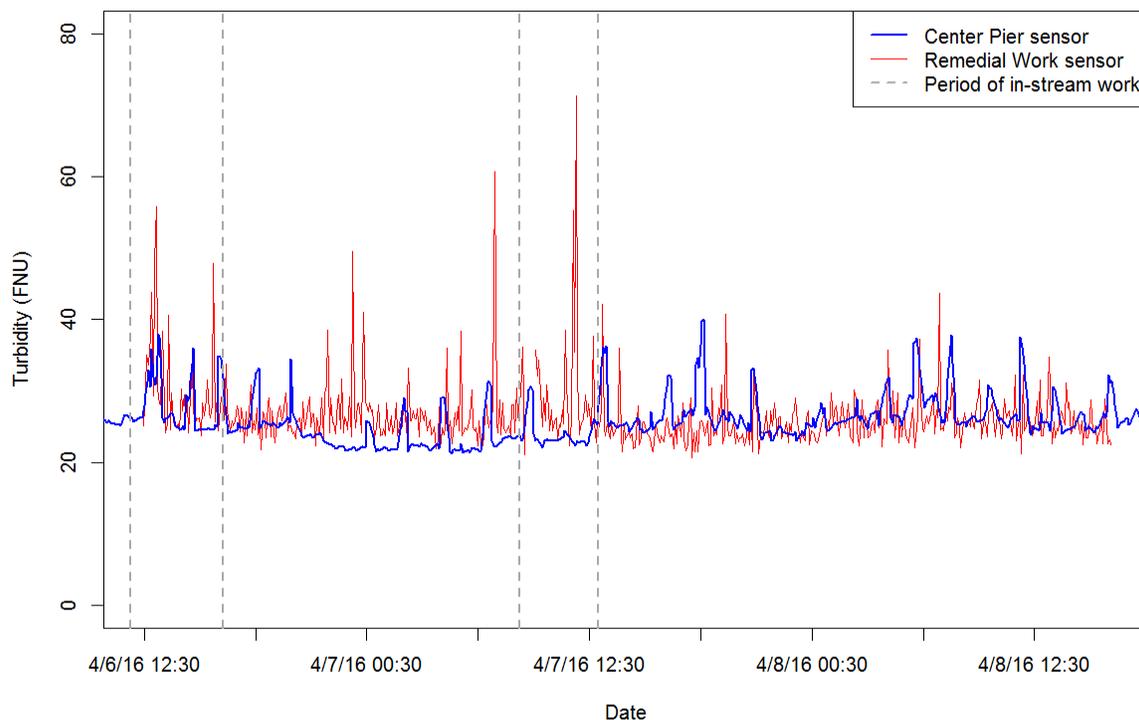
Figure 10   Turbidity from the Center Pier and standalone sensors during the 2016 remedial work.

3.3   SUSPENDED SEDIMENT

As expected, the highest suspended sediment concentrations were sampled immediately downstream of the excavator, while the lowest concentrations were sampled upstream of the operation (Figure 11). More specifically, the mean sampled sediment concentration was 21.1 mg/L upstream of the operation, 157.6 mg/L downstream of the excavator and 32.8 mg/L downstream of the Lower Patch. The same trend was observed in the grainsize of the suspended sediment, where the D_{90} grainsize was 0.3 mm upstream of the operation, 0.6 mm immediately downstream of the excavator and 0.4 mm downstream of the Lower Patch. Note, however, that the overall difference in D_{90} grainsize remains minimal.

The highest suspended sediment concentration was 672.1 mg/L, sampled on April 6th, 2016 at 14:47 directly downstream of the excavator (Figure 12). This sample also had the coarsest D_{90} of all the samples, reaching 0.95 mm. The highest concentrations sampled at the upstream and downstream ends of the Lower Patch were 34.1 mg/L and 90.0 mg/L, respectively. The 90 mg/L sample was collected on the second day of operations when the instream work had progressed to approximately 25 m upstream of the sampling location.
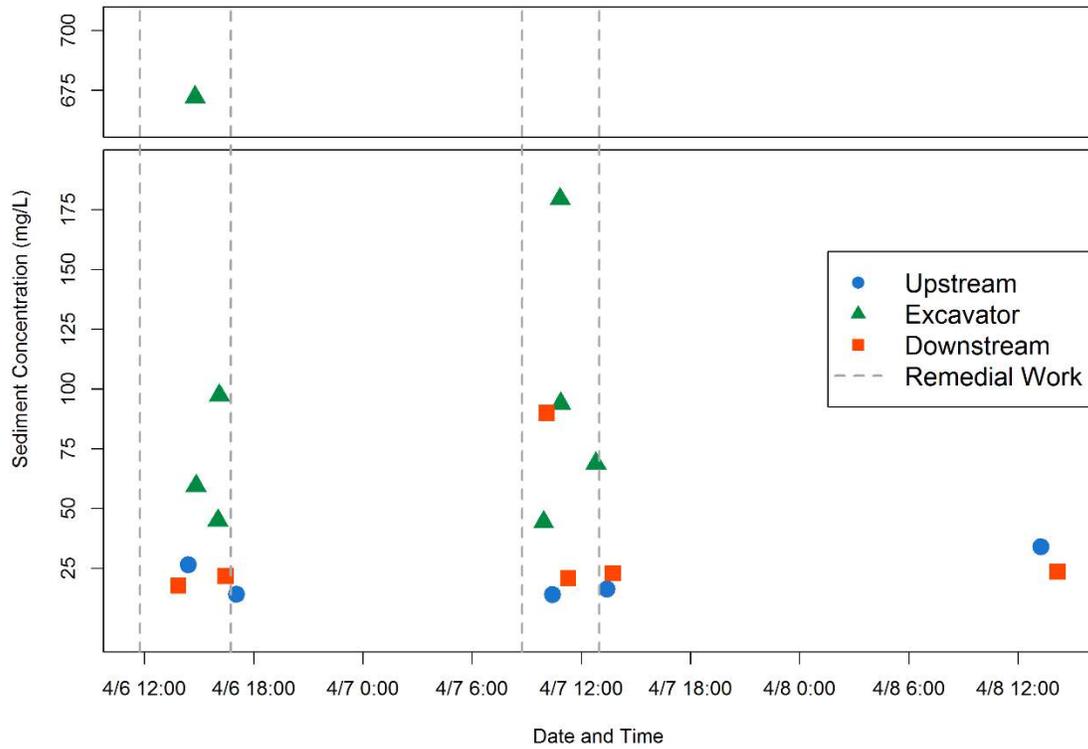
Figure 11   Suspended sediment concentrations sampled during the period of remedial work.

Figure 12   Plume from where the highest concentration of suspended sediment was sampled.

3.4   BEDLOAD SEDIMENT

Contrary to the trend in suspended sediment, where the highest concentrations were measured directly downstream of the excavator, the highest bedload transport rates were sampled at the downstream extent of the Lower Patch (Figure 13). In fact, bedload transport immediately downstream of the excavator was relatively low. The mean transport rate downstream of the excavator was 4.4 g/m/s, compared to the mean transport rates upstream and downstream of the Lower Patch which were 8.4 g/m/s and 13.1 g/m/s, respectively. It is important to note, however, that it is difficult to draw clear conclusions regarding the efficacy of operations using the sampled transport rates due to the inherent variability of sediment transport and the limited number of samples that were collected.

The highest bedload transport rate, 29.4 g/m/s, was sampled downstream of the Lower Patch on April 6th, 2016 at 13:36. This timing corresponds to approximately 2 hours after the start of instream works, when the excavator was roughly 100 m upstream of the sample site. The next highest transport rates, of 22.1 g/m/s and 23.7 g/m/s, were also sampled at the downstream location, but on April 7th, 2016 at 13:42 and 14:57, respectively. This temporally corresponds to shortly after the instream work had been completed around 13:00, when the excavator had been working in the vicinity of the sample site. The amount of bedload being transported into the area from upstream remained relatively constant during the period of remedial work, varying between 3.7 g/m/s and 7.6 g/m/s, except for the one higher sampled rate of 19.2 g/m/s. The D_{84} grainsize of the bedload material at all sampling locations was medium sand between 0.4 mm and 0.5 mm.

Interestingly, the bedload sediment samples taken directly downstream of the excavator contained a large amount of organic material (Figure 14). The mean amount of organic material contained in these samples was 19.3 g, while samples taken at the upstream and downstream ends of the Lower Patch had an average of 0.7 g and 3.7 g, respectively. The maximum amount of organic material within a sample was 47.6 g, compared to 120.9 g of sediment, in a sample collected downstream of the excavator. All organic material was between 2 mm and 22 mm in size and typically consisted of woody debris.
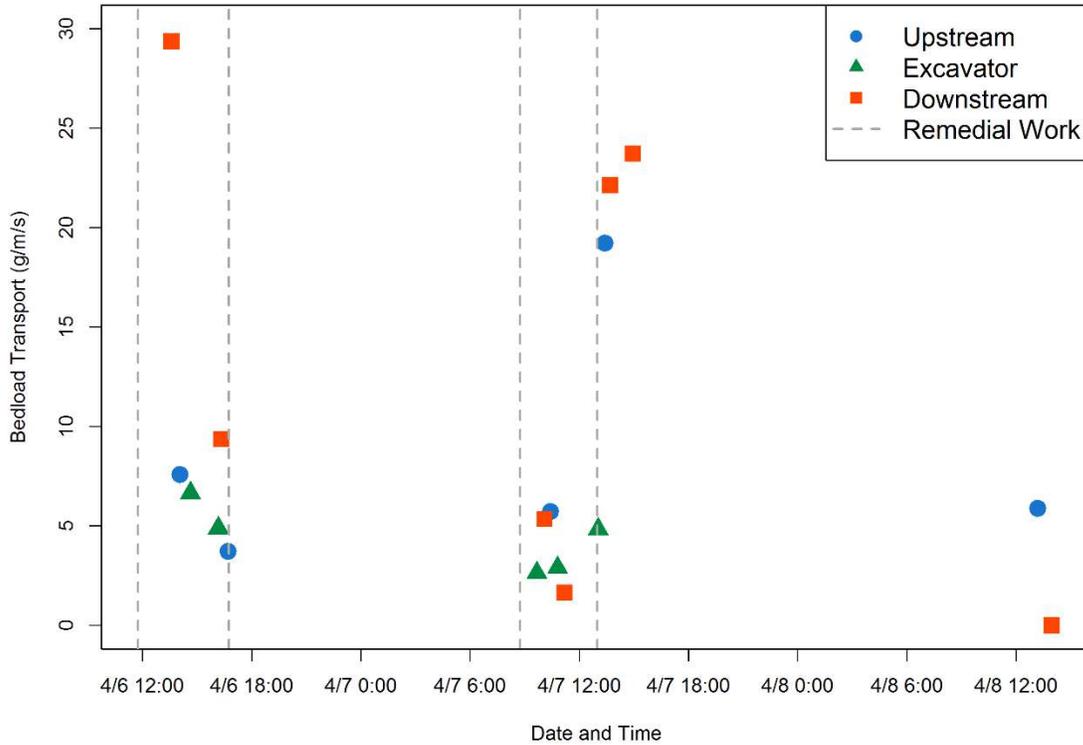
Figure 13   Bedload transport rates sampled during the period of remedial work.
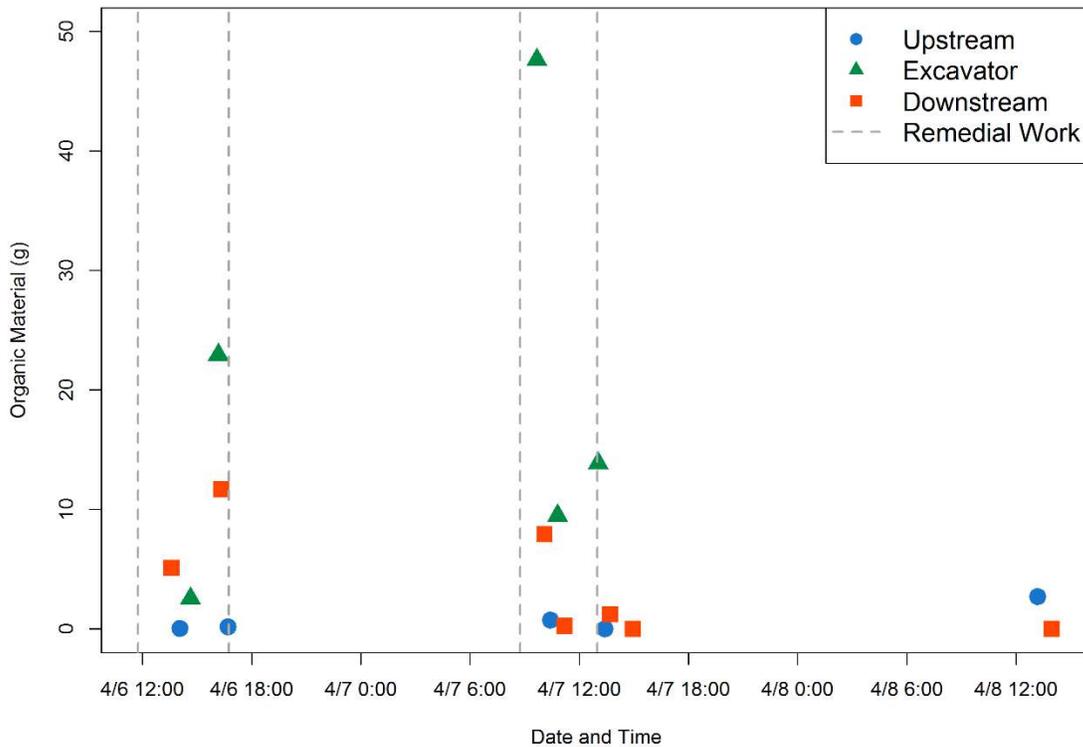

Figure 14   Organic material collected and excluded from the bedload samples.

4 INTERPRETATION AND ANALYSIS

4.1 RESTORATION OF THE SPAWNING SUBSTRATE AND GENERAL ISSUES

Overall, the instream work conducted in 2016 achieved our goal to mechanically remediate the degraded spawning and incubation habitat of the Lower Patch. A number of factors underlie the success of the operation. Foremost was that discharge remained relatively low (75 m^3/s) and constant during the work period, and therefore depth over the spawning pad rarely exceeded the maximum working depth of 1.5 m. Additionally, the sifting technique performed well at this location because its effectiveness is maximized in areas that have a coarse cobble/gravel substrate and sufficient flow velocity to transport fines downstream. The mobility of the excavator was also key because it allowed the site to be easily accessed from the north bank and provided the operation with flexibility in terms of where the work would be done. The experience of the machine operator was equally instrumental as it allowed for the operation to be conducted in turbid water without actually seeing the substrate. Finally, work done in previous years (NHC, 2014; NHC, 2015; NHC, 2016) helped the operation by providing fairly reliable depth estimates, bathymetry mapping and delineation of the Lower Patch location. All in all, these factors contributed to the access and remediation of approximately 75%, or 7,260 m^2, of degraded Lower Patch habitat.

A few general issues arose during the operation, which may or may not be preventable, but nevertheless should be considered in the design of future instream works. As previously mentioned, the turbidity of the Nechako River during spring was not ideal as it prevented any visual confirmation of the spawning pad location and forced the machine operator to rely on experience to determine the appropriate digging depth. Poor visibility also prevented the use of underwater substrate imagery, which would have been useful in determining the effectiveness of the sifting technique and characterizing the surficial substrate composition before and after the operation. The inability to effectively use video monitoring underscores the limited ability to directly measure project effectiveness. Such monitoring could be very important with regard to evaluating how long the remediated condition persists until it is once again infilled.

The second issue encountered was that the handheld GPS unit did not log the excavator track during the first day of operation. However, this issue was preventable and caused by user error. Although equipping the excavator with a more accurate positioning system may be a viable option, the use of a handheld GPS unit placed inside the cab was deemed fully appropriate given the low spatially accuracy required for this kind of instream work. The last issue encountered was along the northwestern extent of the Lower Patch, where insufficient flow velocity and very thick sand and silt deposition rendered the sifting technique ineffective. In this situation, alternative remediation methods such as hydraulic dredging would have been better suited. However, given that these conditions were only observed in a very localized area, we consider mechanical remediation to remain the most appropriate method to restore the Lower Patch substrate.

The trial remediation of the exploratory site located about 550 m downstream of the Burrard Ave. Bridge along the south bank provided further insight into the limitations of using mechanical remediation within the Nechako white sturgeon spawning reach. Although close to known spawning locations, this site did not warrant any cleaning effort because the substrate lacked a coarse size fraction and was dominantly composed of coarse sand and fine gravel. Judging by the trial remediation of this site and from previous work (NHC, 2014) that identified a similar substrate composition to be present downstream of the Burrard Ave. Bridge, mechanical remediation within the spawning reach is likely limited to the areas with placed cobble/gravel substrate or in areas upstream of the Lower Patch comprising coarse native substrate.

4.2   TURBIDITY

Maximum turbidity in the Nechako River was lower in 2016 than in 2015, however the duration of the turbidity pulse associated with spring snowmelt and tributary freshet was longer (Figure 9). This may be because 2015 had more snowfall in January and February, followed by more rain in March which led to rapid melting of the snowpack. Comparatively, the 2016 freshet may have been more drawn-out in reason of the greater rainfall and higher temperatures experienced in April.

Although the relatively turbid water in early April 2016 was not ideal for the instream work because it reduced the visibility of the substrate, it did narrow the gap between the ambient Nechako turbidity level and the local, elevated turbidity plume caused by the excavator. The difference between the maximum turbidity that was recorded directly in the sediment plume and the ambient turbidity was about 45 FNU, however this magnitude of difference was only measured in very a localized spatial and temporal window. Once the distance downstream of the excavator had reached around 150 m, the maximum difference was reduced to about 30 FNU. The relatively rapid dilution of the sediment plume into already turbid water, along with the very short duration of measured turbidity spikes (Figure 10), suggests that the sediment plume caused by the instream work had a relatively localized and temporary impact on the surrounding and downstream turbidity level.

4.3   SUSPENDED SEDIMENT

Throughout the duration of the remedial work, suspended sediment concentrations at the upstream extent of the Lower Patch were relatively low and constant when compared to the other sampling locations (Figure 11). Consistency of these measurements supports that this location was effectively monitoring the background suspended sediment level within the mainstem Nechako, serving as a reference point for comparison with concentrations downstream of the operation. Overall, the trend in mean sediment concentrations suggests that the remedial work was effective in promoting the downstream transport of fine sediment, with mean concentrations of 21.1 mg/L upstream of the operation, 157.6 mg/L downstream of the excavator and 32.8 mg/L downstream of the Lower Patch.

As expected, the highest sediment concentrations were measured immediately downstream from the excavator. Although the maximum concentration sampled within the plume caused by the excavator reached a very high 672.1 mg/L, it would have likely declined rapidly downstream as larger grains settled out of suspension. This is supported by the peak concentration of 90.0 mg/L that was sampled at the downstream extent of the Lower Patch when the excavator was approximately 25 m upstream, assuming both samples had similar initial concentrations. This is further supported by the coarseness of the D_{90} grainsize within this sample (0.95 mm) compared to the mean D_{90} downstream of the Lower Patch (0.4 mm). In fact, 59% of the sediment in this sample was coarser than 0.25 mm medium sand, with 14% being larger than 0.5 mm coarse sand. The size class of this material is consistent with sediment typically transported as bedload over the Lower Patch, infilling the cobble/gravel substrate (NHC, 2016). The rapid settling of this material out of suspension suggests that the remedial work must progress in fairly small downstream increments to effectively coarsen the substrate composition.

4.4   BEDLOAD SEDIMENT TRANSPORT

The bedload transport rate sampled at the upstream extent of the Lower Patch averaged 8.4 g/m/s, with a standard deviation of 6.2 g/m/s. This sampling location spatially corresponds to Site LP 4 in previous reports (NHC, 2015; NHC, 2016), which had a sampled transport rate of 13.4 g/m/s on April 2nd, 2015. These transport rates are relatively similar, despite the fact that discharge was 233 m^3/s in 2015. The maximum transport rate sampled during the remedial work at this location was 19.2 g/m/s, which may have corresponded to the passage of a sand sheet or small dune, as has previously been observed in the area. Overall, the incoming bedload transport rates in 2016 remain consistent with the previously described sediment dynamic of the reach (NHC, 2016), in which relatively low but constant transport is expected over the Lower Patch with higher rates occurring periodically as sand dunes migrate through the middle and northern side-channels of the island complex.

The highest bedload rates were sampled at the downstream end of the Lower Patch (Figure 13), rather than immediately downstream of the excavator as may have been expected. The unexpectedly low rates sampled downstream of the excavator may have occurred because insufficient time had elapsed for the bedload to be transported to the sample location. The three samples taken downstream of the excavator on April 7th, 2016 were 20 m, 29 m and 34 m downstream from the instream work. These samples were collected for a duration of 10 minutes, meaning the bedload would have had to travel at a rate of 2 m to 3.5 m per minute to reach the sampler. However, in two of these cases, the excavator had been working upstream of the sample site for some time prior to sample collection. In the first case, the excavator was operating about 40 m upstream of the sampling location 28 minutes prior to sample collection. In the second case, the machine was working 25 m upstream of the sample site, roughly 15 minutes before sampling began. Both of these cases would still require the bedload to be transported at a velocity of about 1 m per minute just to reach the sampler before the sampling time had elapsed. For comparison, the highest transport rate was sampled at the downstream extent of the Lower Patch about 1 hour and 50 minutes after the instream work began 100 m upstream, translating to a bedload velocity of roughly 0.8 m per minute. The second and third highest sampled transport rates were also sampled at this location at 13:42 and 13:57 on April 7th, 2016 just after the instream work was completed around 13:00, but the excavator had been working about 55 m upstream of the sample location between 12:40 and 12:50 that afternoon. Assuming the sampled bedload was coming from the remedial work, the sediment would have again been travelling at a downstream velocity of 0.8 m to 1 m per minute. All in all, it is likely that bedload velocity contributes to the explanation of why sampled rates were low downstream of the excavator and why they may have been more representative of actual transport rates at the downstream extent of the Lower Patch. Despite the uncertainty created by bedload transport rates and sample timing, the monitoring evidence does support the finding that remediation was effective.

Several other lines of evidence support that the remedial work was effective at dislodging and transporting infilled fines away from the Lower Patch substrate. Firstly, an empty sample was collected at the downstream end of the spawning pad on April 8th, 2016. This sample was taken after the completion of instream work in the same location that had produced the second and third highest transport rates during remedial work, sampled approximately 24 hours prior. Secondly, two additional samples collected after the instream work on April 7th and April 9th returned transport rates of 0.6 g/m/s and 0.0 g/m/s. These samples were taken approximately 10 m away from sites that had transport rates of 4.8 g/m/s and 4.9 g/m/s on April 6th and April 7th, respectively. Comparison of transport rates during and after the remedial work support that bedload transport over the Lower Patch dropped once operations ceased. Although this suggests that the operation was effective at dislodging and transporting infilled fines away from the Lower Patch, it also suggests that incoming bedload will likely re-settle into newly restored interstitial voids because post-operation transport rates upstream of the Lower Patch remained fairly constant; the longevity of treatments was not monitored during the operation.

As previously mentioned, significantly more organic material was collected by the bedload sampler when sampling downstream of the excavator as compared to the upstream (Figure 14). This suggests that a large amount of organic material, primarily consisting of woody debris, had become lodged within the cobble/gravel substrate of the Lower Patch. This may have been the result of high flow conditions experienced in 2015, when overbank flow was contributing a lot of debris to the channel and the Lower Patch area had very low velocity due to backwatering (NHC, 2016). Regardless of whether the organic matter was primarily a consequence of the flood or whether it has slowly accumulated over time, it is representative of the low near-bed velocity present at the Lower Patch and indicates that bed shear stress remains insufficient to mobilize any of the cobble/gravel to release infilled fines.

5   CONCLUSIONS

The 2016 Spawning Substrate Restoration was intended to rapidly improve the quality of white sturgeon spawning substrate and to determine the feasibly of using mechanical remediation as a restorative measure on the Nechako River. Conducted on April 6th and 7th, 2016, the operation effectively accessed approximately 7,260 m^2, or nearly 75% of the degraded Lower Patch spawning and incubation habitat. The instream work was performed during an ideally low discharge of 75 m^3/s, a timing which proved to be both advantageous as local depths were rarely exceeded 1.5 m and problematic because elevated turbidity associated with spring freshet prevented visibility of the substrate. The mechanical remediation, performed using a S2-3 Kaiser 4x4 Spyder Walking Excavator, was completed in about 10 hours.

Monitoring conducted throughout the instream work has indicated that the turbidity plume caused by the excavator had a localized and temporary impact on the surrounding and downstream turbidity level. This is evidenced by the rapidity of turbidity spikes recorded by the sensor installed directly downstream of the instream work, as well as by the similarity between mean turbidity recorded by this sensor and the Center Pier sensor. The maximum turbidity, 71.3 FNU, was recorded when the excavator was working approximately 17 m directly upstream from the sensor, which was about 45 FNU higher than the ambient turbidity of the mainstem Nechako. When the excavator was around 150 m upstream from the sensor, maximum turbidity decreased to 55.9 FNU, or about 30 FNU above the background level.

The highest suspended sediment concentrations were sampled immediately downstream of the excavator, while concentrations upstream of the remedial work remained relatively low and constant. Mean sediment concentrations upstream of the operation, downstream of the excavator and downstream of the Lower Patch were 21.1 mg/L, 157.6 mg/L and 32.8 mg/L, respectively. The upstream to downstream trend in sediment concentration provides a good indication that the mechanical remediation was effective in promoting the downstream transport of fine sediment. The efficacy of the sifting technique to dislodge infilled fines is further supported by the size class of suspended material because it corresponds to sediment typically transported as bedload over the Lower Patch. However, differences in the concentration and grainsize of samples taken behind the excavator as opposed to those taken further downstream suggest this infilled material likely settles out of suspension rapidly, emphasizing the need for the remedial work to progress in relatively small downstream increments.

The amount of bedload entering the area from upstream remained fairly low and constant, ranging from 3.7 g/m/s to 7.6 g/m/s, except for the one higher sampled rate of 19.2 g/m/s. These rates remain consistent with data collected in 2015 and continue to reflect the current description of reach-scale sediment dynamics (NHC, 2016), in which relatively low but constant transport is expected over the Lower Patch with higher rates occurring periodically as sand dunes migrate out of the island complex. The highest bedload transport rates were sampled at the downstream end of the Lower Patch and ranged from 22.1 g/m/s to 29.4 g/m/s. While samples collected immediately downstream of the excavator had surprisingly low transport rates, back-calculating the velocity of sediment transported over the Lower Patch revealed that there may have been insufficient time for much of the sediment to reach the sampler. Additional sampling conducted in the days following the operation showed that transport rates on the Lower Patch dropped once the instream work ceased, with samples returning transport rates of 0.0 g/m/s, 0.6 g/m/s and 0.0 g/m/s near locations that previously had rates of 23.7 g/m/s, 4.8 g/m/s and 4.9 g/m/s. Although this suggests the operation dislodged infilled fines, it also suggests that incoming bedload is likely to deposit within newly restored interstitial voids.

The significant amount of organic debris collected by the bedload sampler downstream of the remedial work reflects the low near-bed velocity present at the Lower Patch. This, in combination with the supply of bedload sediment stored upstream within the island complex, highlights the importance of periodically mobilizing the static cobble/gravel substrate to release infilled fines. While several restorative strategies may exist to achieve this, mechanical remediation performed as part of the 2016 Spawning Substrate Restoration project proved to be an effective means to immediately improve the quality of white sturgeon spawning substrate.

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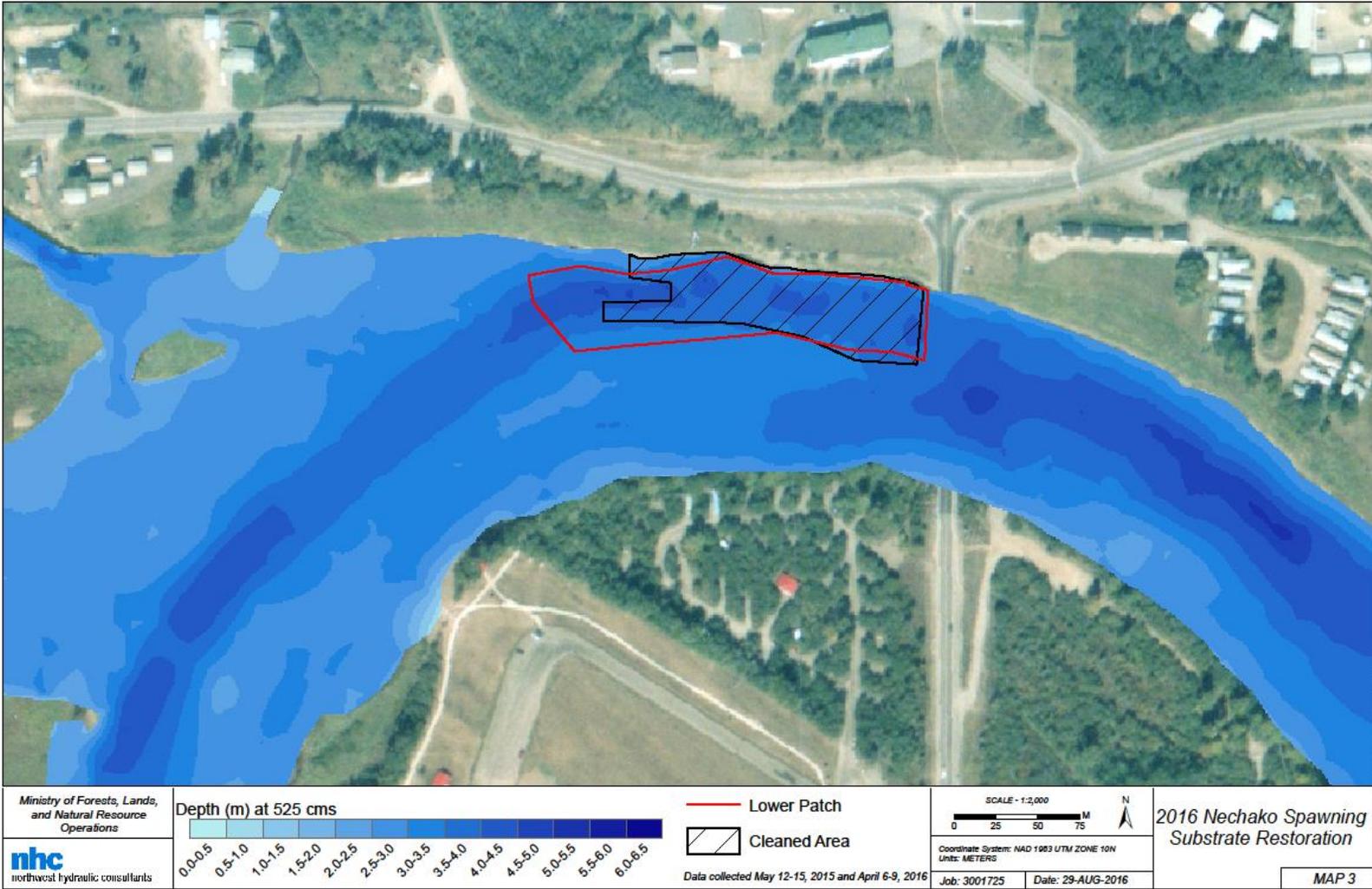
MAPS

Map 1   Sampling locations and area of Lower Patch restored in 2016
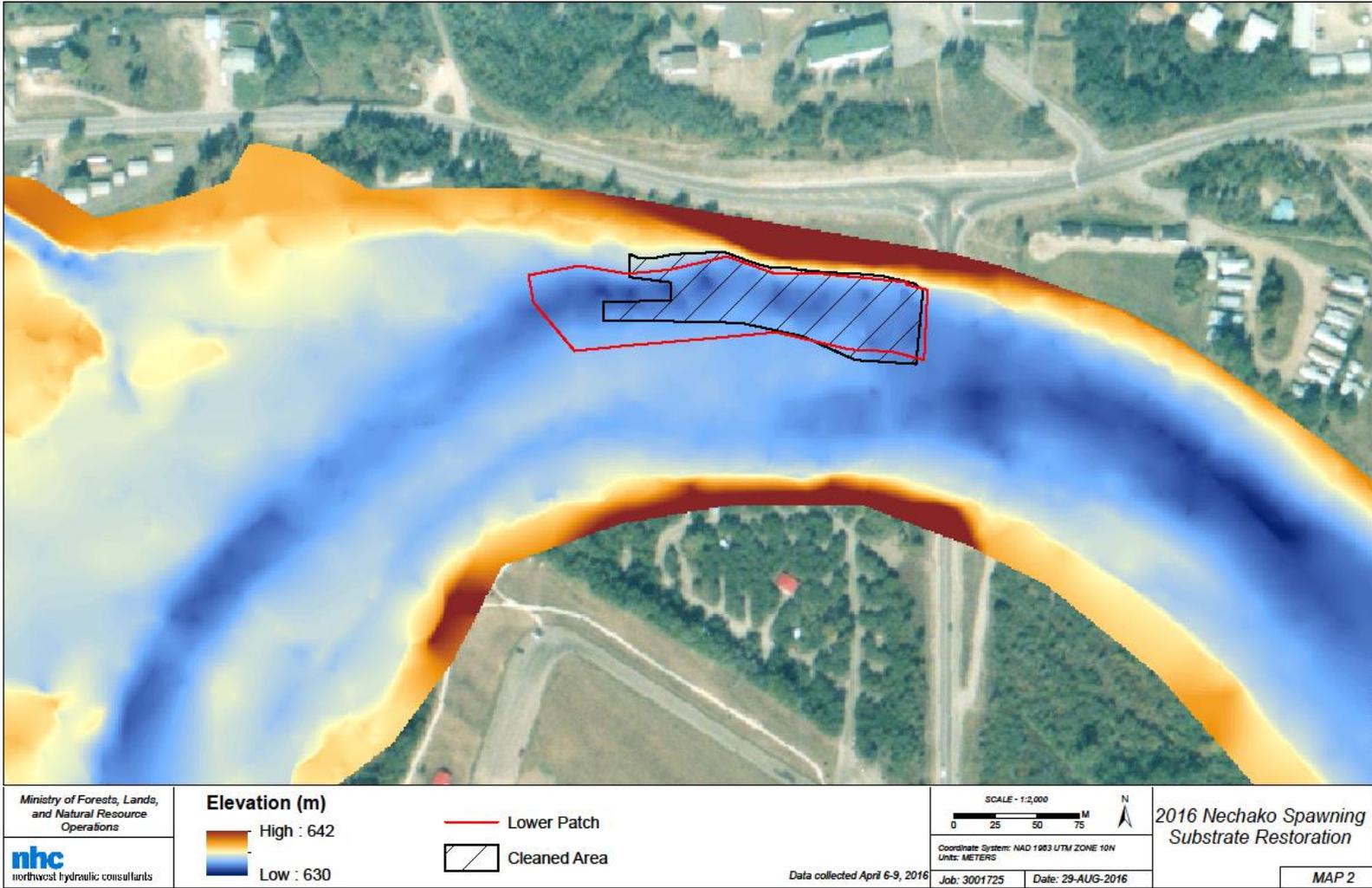
Map 2   Spatial coverage of the remedial work in 2016 with bed elevation

Map 3   Spatial coverage of the remedial work in 2016 with water depth measured during a discharge of 525 m³/s.