Through Ice Bed Material Sampling to Determine Main Channel Bed Material Gradation on a Large Seasonably Turbid River

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Extended Abstract

River morphological studies depend on knowledge of main channel bed material gradations. Field efforts focused on assessing bed materials are highly challenging when presented with large scale rivers having deep, swift, and typically turbid glacially supplied seasonal flows. The high turbidities from glacial runoff and the associated fine particle mobilization precludes the application of standard visual sampling techniques for much of the year, and swift and deep flow greatly restricts the use of other sampling techniques, such as by dredge samplers. The Susitna River, located in Alaska, has all the traits associated with a river posing difficulty for geomorphic field assessment.

The glacially sourced headwaters of the Susitna River supply highly turbid flow during the open-water period, generally occurring between mid-May and mid-October. An example of the highly turbid flow conditions is shown in Figure 1, in which the instrumentation cable is obscured by the relatively shallow turbid water. The ice-cover period persists during the remainder of the year and the river receives a substantially lower amount of glacial inflow due to freezing conditions in the headwaters. Because of the lower glacial inflow during the ice-cover period, the turbidities within the Susitna River can be up to 100 times less than during the open-water period. An example of the less turbid and clearer water conditions during the ice-cover period is shown in Figure 2, which is a still frame image extracted from the through ice methods described by this extended abstract.

As part of a larger geomorphic study effort on the Susitna River, transported bed material was characterized at bar head locations using surface and subsurface sampling during relatively lower flow portions of the open-water period. To understand the presence of coarser bed material vertical layers and longitudinal deposits (i.e. armor layers and lag deposits), a method was needed to investigate the main channel bed materials. A methodology was developed to collect samples during the ice-cover period, taking advantage of low turbidities and low flows. The developed method consisted of lowering underwater cameras through augered holes in river ice to obtain images of the channel bed, rectifying the underwater images to remove distortion, and measuring bed material particles observed in the rectified images.

Image rectification was achieved by calibrating the underwater camera by taking underwater images of a 0.15-meter square calibration grid submerged in a quiescent pool. The calibration grid images were then analyzed using photogrammetric techniques and software to measure the distance between grid points for each of the images obtained at different camera heights above the calibration grid, and the camera focal length and distortion parameters were computed.

Images of the studied channel bed were collected at over 20 locations along 400-kilometers of the Susitna River during the ice-covered period. Sample transect locations were planned and then adjusted during the field assessment. Following sample transect location determination, exploratory holes were augered along the transect to determine the lateral extent of flow beneath the river ice. The depth of the flow was then measured to determine the number of sample holes needed for each transect, with the goal of measuring approximately 100 surficial bed material particles from each transect. The sample holes locations were then laid out and snow was cleared from those locations to assist with augering. The underwater camera, mounted to an adjustable pole, was then lowered through the holes with flowing water and not completely frozen to the bed, until the base of the pole reached the river bed. The camera mounting position on the adjustable pole was varied based on the depth of flow, ice thickness, and the size of the bed material observed in initial images. The underwater camera was operated in video mode for the bed image acquisition to take advantage of the camera's automated low-light adjustment. Once the pole was on the river bed, it was positioned vertically and held in place for a minimum of 10 seconds to ensure that multiple video frames were available for post-processing extraction of still frame images for bed material gradation analysis. Each sample hole video was inspected to ensure adequate scene illumination and mounting position based on the bed material size. Adjustments and repeated imaging were performed if warranted. Examples of sample videos are viewable at https://youtu.be/v79bMJv4Vfs or by using the QR code provided in Figure 3.

After the field work, a still frame image of the bed material was extracted for each sample hole video. The extracted still frame images were then rectified, using the developed calibration parameters to remove camera lens distortion. Figure 4 shows an example of an unrectified extracted still frame image and Figure 5 shows an example of a rectified still frame image. Repeatable particle count methods were determined and used with standardized digital sampling grids established with GIS software to count individual bed material particles measured on each photograph. Approximately 100 particles were measured at each sample transect to develop grain size distributions in each 0.4 phi size bin. The effort demonstrated a practical technique to collect bed material samples within the main channel of rivers with challenging field work conditions. The results are compared with open-water period obtained bar head sample locations in Figure 6.

Figure 1. Typical high turbidity conditions for glacially supplied rivers during the open-water period.

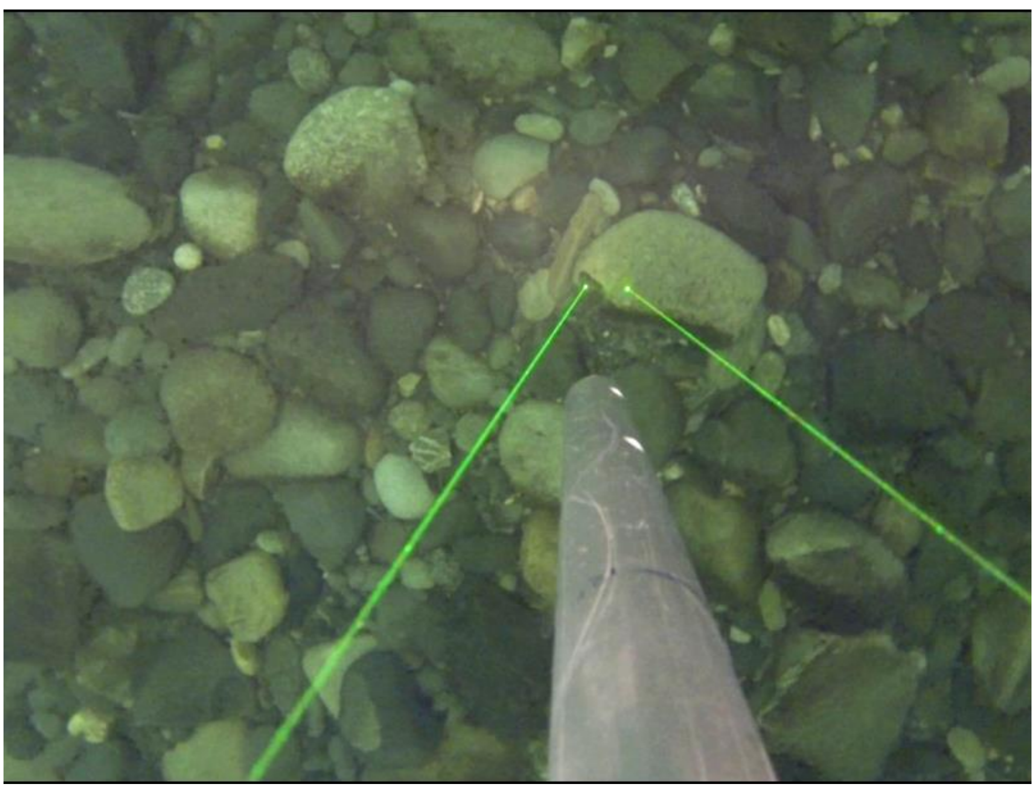

Figure 2. Typical low turbidity during ice-cover period. Freezing conditions in headwaters reduces glacial input.

Figure 3. QR code link to example through ice bed imaging sample video

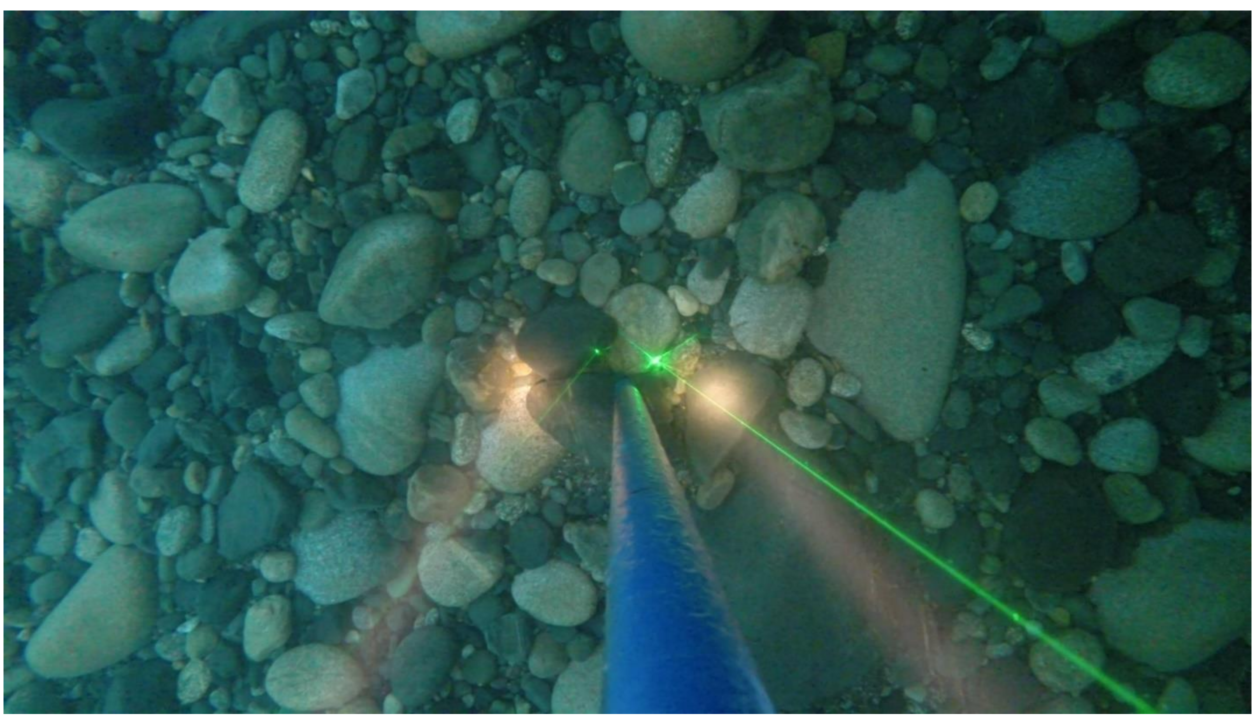

Figure 4. Unrectified example still frame image extracted from through ice bed image sample video

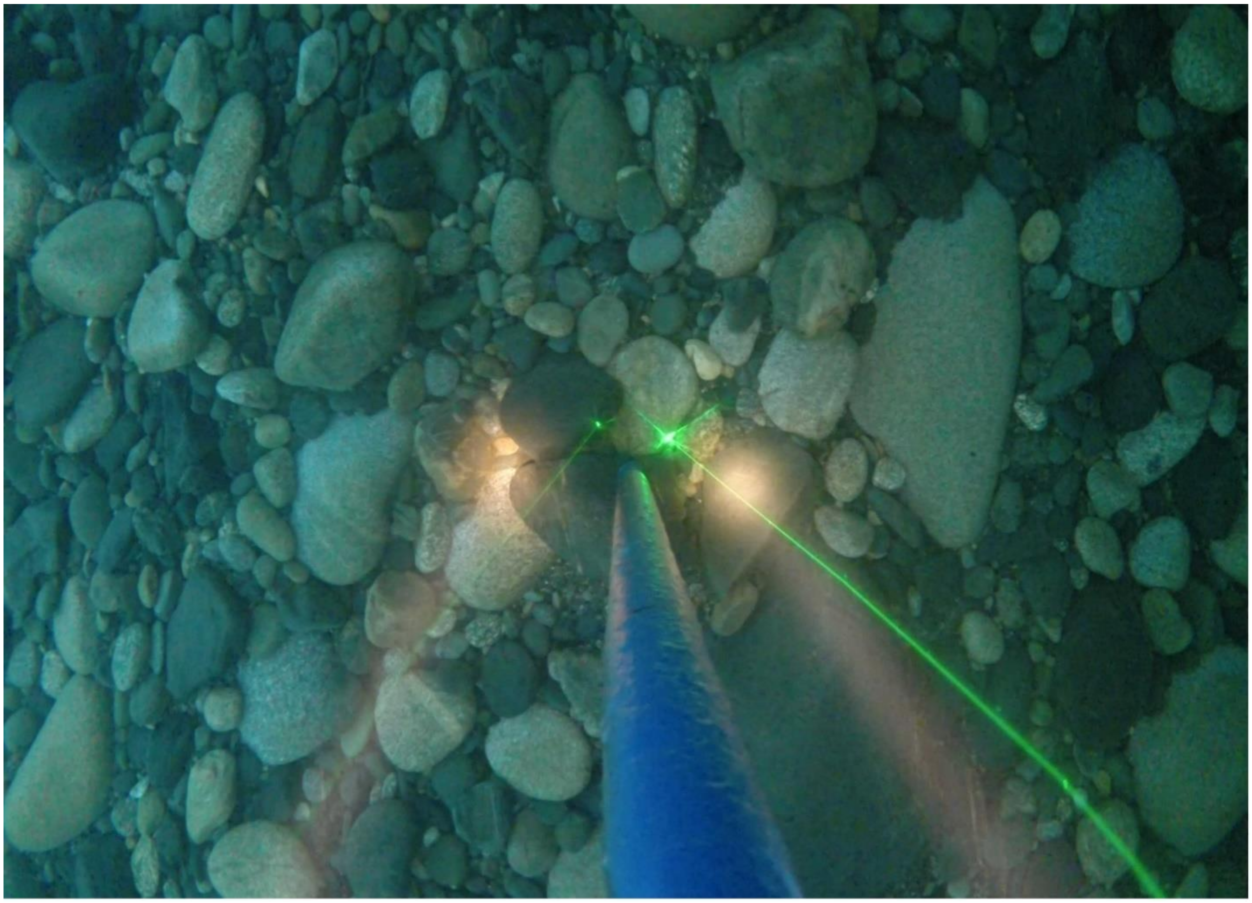

Figure 5. Rectified example still frame image extracted from through ice bed image sample video

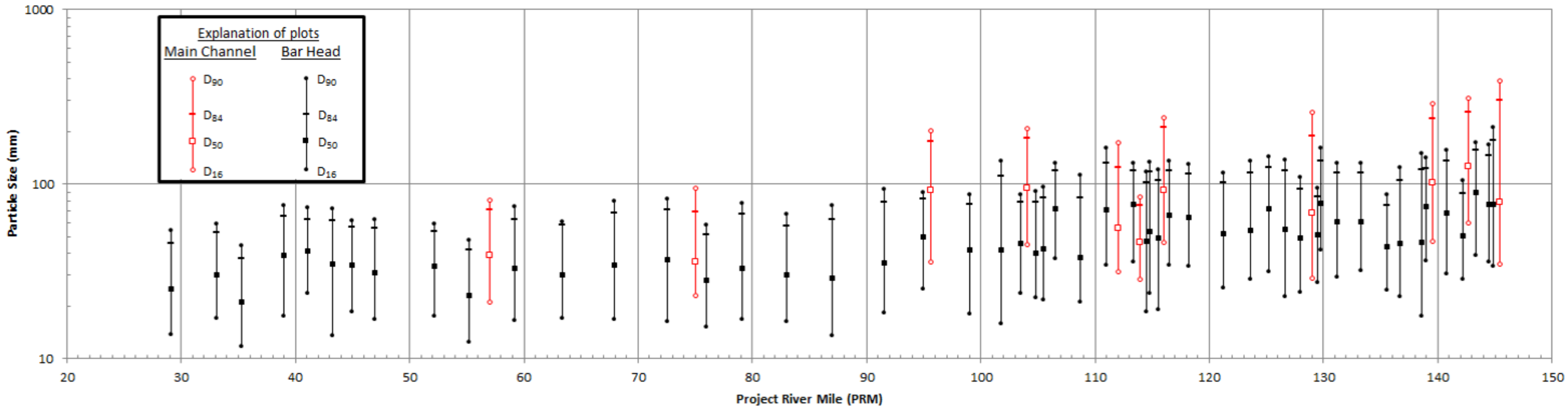

Figure 6. Comparison of ice-cover period through-ice bed image and open-water period bar head sample grain size analyses results.