Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fluvial Geomorphology Modeling Below Watana Dam (Study 6.6)

Winter Sampling of Main Channel Bed Material Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
AOI	Area of Interest
AOW	Additional open water
AT	Aerotriangulation
cfs	cubic feet per second
DEM	Digital Elevation Modern
DMC	Digital Mapping Camera
DTM	Digital Terrain Model
FERC	Federal Energy Regulatory Commission
FIPS	Federal Information Processing Standard
GIS	Geographic Information System
GPS	Global Positioning System. A system of radio-emitting and -receiving satellites used for determining positions on the earth.
Hz	Hertz
ILP	Integrated Licensing Process
IMU	Inertial measurement unit
LiDAR	Light Detection and Ranging
LR	Lower River Segment
MR	Middle River Segment
NAD	North American Datum
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
PRM	Project River Mile
QC	Quality control
RM	River Mile(s)
SC	side channel
USGS	U.S. Geological Survey

SUMMARY

Accuracy of 1-D and 2-D bed evolution modeling is reliant on input data, including bed material gradations. The quantification of main channel bed material is of particular importance to simulation of bed response The determination of the bed material gradations for the deepest portions of the Susitna River main channel has not previously been performed. As such, the confirmation of whether bar head material gradations collected in the shallower portions of the main channel are representative bed material in the deepest portions of main channel material was undetermined and 1-D and 2-D bed evolution model inputs were incomplete. The pebble count methods applied to bar heads during the summer 2013 and 2014 field seasons may not be applicable to the main channel, since pebbles in the deepest portions of the Susitna River cannot be reached by hand. In addition, the main channel bed material cannot be sampled during the open water period as the material is too large to retrieve with a dredge sampler and the turbidity is too great to use visual sampling techniques. However, turbidity is greatly reduced during the winter period, when glacial inflows and associated fine particle input is minimal, suggesting the possibility visually sampling bed material during the winter period.

In order to evaluate the potential of visually sampling the bed material during the winter period of lower turbidity, the Fluvial Geomorphology Modeling Study (Study 6.6) conducted a test during the winter of 2012/2013 using underwater cameras lowered through holes in the river ice (Tetra Tech 2013). This test was successful and used to prepare methods to obtain bed material photographs for the deepest portions of the Susitna River and two major tributaries. The data obtained from the winter 2013/2014 effort is presented in this memorandum and provides the first quantitative assessment of bed material sizes in the deepest portions of the Susitna River main channel. The data serves to support development of inputs for the 1-D and 2-D bed evolution modeling efforts.

Bed material sampling was conducted for the main channel of the Susitna River, and at locations on the Chulitna River and Talkeetna River, between March 17 and April 4, 2014. Photographic sample images of the bed material were obtained at transect locations, at which multiple holes were augered through the river ice and underwater cameras mounted were lowered through the holes. A total of 23 transects were sampled along the Susitna River, including five in the Upper River study segment, 12 in the Middle River study segment, and six in the Lower River study segment. Additionally, two transects were sampled on the Chulitna River and two transects were sampled on the Talkeetna River.

The bed material photographs were rectified using photogrammetric post-processing techniques in order to more precisely determine the size of individual bed material particles by removing camera lens distortion and determining measurement scales for the photographs. Particle sizes were measured and used to determine grain size distributions and size descriptor (i.e. D_{16}, D_{50}, D_{84}, and D_{90}) values for each transect. The results showed that the bed material in the deepest portions of the main channel of the Susitna River is appreciably larger than those obtained from the summer bar head sampling in all geomorphic reaches of the Middle River and geomorphic reach LR-1 of the Lower River. However, the winter samples obtained in LR-2 and LR-3 of Lower River in the deepest portions of the channel were very similar to the bar head samples obtained from the shallower portions of the channel.

The winter of 2013/2014 sampling effort achieved its objectives as well as those for the 2014/2015 winter season. The number of transect locations identified for sampling prior to the field work were

expected to be acquired during both the 2013/2014 and 2014/2015 winter periods; however, favorable conditions and efficient methods allowed for all transects to be acquired during the 2013/2014 winter period and no locations need to be sampled during the 2014/2015 winter period. The data collected during the winter sampling are considered sufficient for the bed characterization purposes and for the intended use in the reach-scale bed evolution modeling of the Middle and Lower Susitna River Segments including the Chulitna and Talkeetna Rivers.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 320-mile-long river in the Southcentral region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. The results of this study will provide information needed to support the FERC's National Environmental Policy Act analysis for the Project license.

Bed material sampling using pebble count techniques conducted in the summer field season of 2013 and 2014 cannot reach the deepest portions of the Susitna River main channel. In addition, bed material cannot be sampled during the open water period as the material is too large to retrieve with a dredge sampler and the turbidity is too great to use visual sampling techniques. In the 2013 summer field season 22 bar heads were sampled in the Lower Susitna River (every 3.5 miles on average) and 30 bar heads were sampled in the Middle Susitna River (every 1.4 miles on average including Focus Areas). In the 2014 summer field season an additional 19 bar head samples were collected in the Middle Susitna River and 3 bar head samples were collected in the Upper Susitna River. These bar head samples included surface pebble counts and subsurface samples that were field and laboratory sieved. Bar heads were selected because they are representative of alluvially transported material, but may not accurately represent material in the deepest portions of the channel. The USGS has tried to sample the bed material in the deepest portions of the channel at their gaging sites as part of their sediment transport study and has not been successful.

Knowledge of the size of the bed material in the center of the channel is important to accurately predict the bed response in the 1-D and 2-D bed evolution modeling efforts. The bed material in the deeper portions of the channel may be coarser than the heads of bars and channel margins sampled during the summer, but without quantified measurements the grain size distribution can only be estimated for the center channel or inferred from modeling. To investigate alternate means to sample the bed material in the deepest portions of the Susitna River, the Fluvial Geomorphology Modeling Study (Study 6.6) in the winter of 2012/2013 conducted a test of visually sampling the bed material by lowering underwater cameras, with parallel mounted lasers for reference scaling of particles through the ice. The test was successful in that adequately clear photos were obtained of the channel bed from which bed material size distributions could be developed (Tetra Tech 2013). Based on this test, sampling of main channel bed material during the winter of 2013/2014 was recommended to obtain data needed to support the Fluvial Geomorphology Modeling Study (Study 6.6) and the associated bed evolution modeling analyses. This effort is identified in RSP Section 6.6.4.1.2.9.1 and Study 6.6 ISR Sections 4.1.2.9.1.2 and 5.1.9.1. This technical memorandum describes the methods and provides the results from analysis of the main channel bed material underwater photographic samples for the determination of bed material gradations conducted during the winter of 2013/2014 study.

2. STUDY OBJECTIVES

The overall purpose of the work presented in this technical memorandum is to quantify main channel bed material gradations at selected sites in the Upper, Middle, and Lower Susitna River Segments. The data obtained from this study serves as valuable input for the 1-D and 2-D bed evolution modeling efforts being conducted under the Fluvial Geomorphology Modeling Study (Study 6.6).

3. STUDY AREA

3.1. General

The Susitna River located in Southcentral Alaska drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna, and East Fork Susitna glaciers to Cook Inlet (U.S. Geological Survey [USGS] 2012). The Susitna River Basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands, and on the south by Cook Inlet. The highest elevation in the basin is at Mt. McKinley at 20,320 feet while its lowest elevation is at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna, and Yentna rivers, which are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29^{o} F.

3.2. Susitna River Segments

The overall study area extends from Cook Inlet to the Maclaren River confluence at PRM 261.3. Within the geomorphology study area, the Susitna River has been subdivided into three segments whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle, and Lower Susitna River Segments and are identified in Figure 3.2-1 with the associated extents:

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3 / RM 260) downstream to the proposed Watana Dam site (PRM 187.1 / RM 184).[1]
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1 / RM 184) downstream to the Three Rivers Confluence (PRM 102.4 / RM 98.5).
- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4 / RM 98.5) downstream to Cook Inlet (PRM 3.3 / RM 0).

[1] Note: Project River Miles (PRMs) are the river mile system used for the current Susitna-Watana Project. River Miles (RMs) were the river mile system used in the 1980s project. The PRM delineation starts about 3 miles farther into Cook Inlet than the RMs and has a slightly different thalweg than that of the 1980s. Thus, PRM values are generally 3 to 4 miles higher than the RM values. Because this analysis is a temporal comparison, both systems are referenced.

The study effort for the work presented in this technical memorandum covers each of the three Susitna River Segments, the Upper, Middle, and Lower segments. Additionally, two samples were collected on the Chulitna River and two samples were collected on the Talkeetna River.

The upstream-most segment, referred to as the Upper River (UR), extends from PRM 261.3 to PRM 187.1 at the Watana Dam site. The morphologic characteristics of this segment of the river are dominated by the products of Quaternary-age glaciation that overlie bedrock outcrop and a non-alluvially forced planform controlled by bedrock outcrop. The planform, which is quite sinuous in parts of the Upper River (i.e., UR-2), is antecedent but there is little evidence of significant lateral migration of the channel under current hydrologic and sedimentologic regimes (Tetra Tech 2014a).

The Middle River (MR) segment extends from the Watana Dam site to the Three Rivers Confluence at about PRM 102.4 (RM 98.5). The general characteristics of the river in this segment are heavily influenced by bedrock outcrop as well as Quaternary-age glaciations (Tetra Tech 2014a).

The Lower River (LR) segment extends from the Three Rivers Confluence (PRM 102.4 / RM 98.5) to the tidal flats at Cook Inlet (PRM 3.3 / RM 0). The morphologic characteristics of the river in this segment are dominated by sediment loading from the major tributaries and variable resistance to erosion of the Pleistocene-age, glacially-derived materials including tills (moraines), glacio-fluvial sediments in various elevation outwash-surfaces, and glacio-lacustrine sediments that control the width of the valley (Tetra Tech 2014a).

4. METHODS

Bed-material data in the deepest portions of the main channel is difficult to collect under open-water conditions on the Susitna River. During the open-water period, flows are typically high and associated higher river stages make shallow water or dry pebble count methods in the deeper parts of the channel infeasible. Turbidity associated with the open-water period glacial melt and runoff significantly reduces visibility, and prevents the use of alternative sampling methods such as the use of underwater cameras. However, during the wintertime ice-covered period, the turbidity is about 100 times less (Tetra Tech 2013) and visibility is good. The recommendations from Tetra Tech (2013) were utilized for the bed material sampling during the 2013/2014 winter period, between March 17 and April 4, 2014. The detailed methods for sample site selection, data acquisition, camera calibration, and data processing are described in this section.

4.1. Field Sample Site Selection

The 2013/2014 effort was initially intended to sample the Middle River and the Three Rivers Confluence Area only; however, favorable conditions and efficient field methods allowed for collection of sample data for the Lower River and Upper River as well. Thus, both the efforts planned for the winters of 2013/2014 and 2014/2015 were completed in the winter of 2013/2014. A total of 27 transect locations were sampled, 23 of which were located on the Susitna River, and two each were located on the major tributaries, the Chulitna River and Talkeetna River. Sample sites were first identified based on data needs considering modeling efforts and geomorphic field data obtained during the summer 2013 field period.

Helicopter supported transport allowed for aerial visual identification of the desired sample locations and efficient adjustment of the sample location if the initially identified location was deemed unfit for sampling. In the field, sample transect locations were adjusted for safety considerations due to open leads and landing areas. Additionally, helicopter transport increased the efficiency of movement between sample transect locations which allowed for multiple transect samples per day.

Table 4.1-1 identifies the transect locations, number of photographs, sample date, and estimated presence of coarse main channel bed "lag deposits". Lag deposits consist of coarse material that remains after finer material has been winnowed and transported downstream. These locations are important as the bed may be comprised of considerably coarser material than other nearby areas. The coarser material, possibly including boulders, can act as vertical controls that limit the potential for channel downcutting.

The initial intent was to collect approximately 12 photographic samples from holes augered through the ice on the sample transect. The actual number of sample photographs obtained per transect varied due to site conditions, but was on average 15 photographs per transect and at only four transects were fewer than 12 photographs obtained. Locations selected in the field for the transects and individual augered holes for each photograph were affected by factors such as ice conditions, weather, travel time to sample locations, turbidity, and river flows. After the main channel was identified from aerial viewing of the predetermined approximate sample transect location, landing areas and open leads were accounted for to determine the desired sample transect location (Figure 4.1-1). Exploratory holes were then augered along the selected transect to determine the best locations for main channel sample holes, considering the aforementioned factors.

4.2. Field Data Acquisition

Exploratory holes were augered along the sample transect and tested for ice thickness, flow depth below the ice, and general water clarity as evidenced by water color and frazil ice present in the augered hole. Sample holes were spaced at approximately 8-10 feet apart to prevent duplication of bed material particles photographed. Once the sample hole locations were determined to satisfy conditions for photographic sampling, the underwater camera was adjusted to an appropriate initial sample height above the bed based on available flow depth below the bottom of the ice. Sample height intervals used in the field were standardized as 4 feet above the bed, 3 feet above the bed, and 2 feet above the bed. This standardization allowed for calibration of the camera and post-processed rectification of the sample photographs. Sample photographs were obtained using a GoPro Hero3+ Black Edition (GoPro) video camera and two Pelican SabreLite 2000 submersible flashlights mounted on Marshalltown aluminum push button handle sections. Ice thickness and water depth were measured to select which sample height to use for the initial sample video, and for the addition of handle sections to allow the bottom of the pole to reach the river bed material and provide sufficient pole length for stabilization of the camera.

Sample photographs were obtained using the GoPro 1080 superview video mode. Once the bottom of the pole contacted the bed material, the pole was positioned vertically above the river bed and held in place for a minimum of 10 seconds to ensure multiple video frames would be available for post-processing still frame extraction. After each sample video was obtained, it was reviewed in the field using the GoPro smartphone application. If the sample video was deemed insufficient due to scene illumination or bed material size (larger bed material requires a larger field of view to obtain an appropriate number of particles for sampling), it was repeated for the same sample hole using varying sample bed heights until determined acceptable. The camera height above the bed determined acceptable was then used for each sample hole for photographic consistency along the transect. For data processing, still frame images were extracted from the video files obtained from each sample hole and saved as JPEG image files.

An exception to this method was applied at the sample transect located at Susitna River PRM 21.8, at which the sample photographs indicated a majority of sand bed material. The camera height was varied across the transect for qualitative visual inspection of the sandy bed material, and the resulting sample images were not further processed for quantitative gradation determination since the material was primarily sand.

4.3. Underwater Camera Calibration

Calibration of the GoPro camera was necessary in order to accurately measure the bed material particle sizes obtained in the photographs. The camera calibration was performed in a controlled setting, independently from the field sampling of the river bed material, by obtaining underwater photographs of a calibration grid in a quiescent swimming pool. These underwater photographs were used to compute calibration parameters for the camera. The calibration parameters were then applied to rectify each of the river bed material sample images so that distances in the images could be measured. The calibration process for the sample photographs can be divided in three steps:

- Acquisition of the calibration images,
- Computing calibration parameters of the camera, and
- Applying the calibration parameters to ‘rectify’ the sample bed material images.

Several factors permitted the calibration to be performed.

- The riverbed images were taken with the camera facing straight down. A spirit level was used during exposure to keep the pole to which the camera was attached level. At the same time the riverbed was essentially flat in the area photographed. This made it unnecessary to obtain stereo images and made it possible to rectify individual images.
- The camera could not be focused, that means it has a fixed focal length. This was a requirement for calibration.

The method of measuring coordinates from imagery is an established technology and is typically referred to as photogrammetry. Photogrammetry is not only used for topographic mapping from aerial images, but also for close range and industrial applications, both terrestrial and underwater. Usually specialized metric cameras are used for acquisition of photographs processed for measurement. However, a range of cameras are being used as well, including GoPro cameras for mapping underwater features and for mapping terrestrial features from unmanned aerial systems.

The camera calibration parameters approach consisted of:

- camera focal length,
- size of the image, and

- parameters describing the distortions of the camera lens.

The GoPro Hero3+ is a 12 megapixel camera that has an internal Sony image sensor with approximately 3,000 by 4,000 pixels and an individual pixel size of 1.55 micron or 0.00155 mm. The frame size of the 1080 superview video mode, which was used for the underwater bed material sample photographs, is 1,920 by 1,080 pixels. The field of view that is captured in video mode is the same as the field of view captured in full size image mode. That means that in video mode the individual pixels are larger than 1.55 micron. These larger pixels result from averaging several pixels of 1.55 micron. Based on these factors the pixel size was computed for the bed material images.

The camera was used to acquire underwater photographs of a rigid calibration grid placed on the bottom of a swimming pool. The calibration grid had a point spacing, or grid cell size, of 6 inches by 6 inches. These photographs were analyzed to determine the camera's focal length and lens distortion parameters. An example of a raw and unrectified underwater photograph of the calibration grid is shown in Figure 4.3-1, which clearly shows distortion in the raw image, as the grid cells near the edge of the image are distorted and are not square. Photographs were taken of the calibration grid for each of the corresponding heights (4 feet, 3 feet, and 2 feet) above the bed as used to obtain the field sample photographs. The calibration grid photographs were taken using the same video mode as the field sample photographs of the bed material.

Individual still frame images were extracted during post-processing of the calibration grid video files. The still frame images were then imported into the Trimble Inpho photogrammetric software and the distance between the calibration grid points were measured for each of the images obtained at different heights. The real world coordinates of the calibration grid were entered into the software. Using the photogrammetric software, the camera focal length and distortion parameters were computed.

4.4. Rectification of Bed Material Sample Photographs

The results obtained by photogrammetric software analysis of the still frame images of the calibration grid were used to rectify each of the field sample photographs. The camera calibration parameters were applied to each image using the Trimble Inpho software in order to remove distortions. The rectified images obtain a scale reference that can be used for measurement of particle grain size by importing the image in GIS or CAD software and measuring distances in the desired units.

Verification of the calibration and rectification process was performed by measuring the distance between the calibration grid points. Figure 4.4-1 shows the rectified version of the image previously shown in Figure 4.3-1. The grid cells shown in the rectified image of Figure 4.4-1 are square. The rectified image was loaded into a GIS viewer and the 1 foot distance measured between two grid points was determined as 1.02 feet in the rectified image. This indicates that there is only a 2 percent error due to the distortion of the camera lens after applying the rectification process.

4.5. Determination of Bed Material Gradation

After each of the field sample photographs was rectified with the calibration parameters, the bed material gradations were determined. Digital sample point grids with uniform spacing were created as GIS shapefiles. For each transect, the objective was to measure approximately 100 bed material particles, for consistency with the pebble count methods applied during the summer field period pebble counts. The number of sample points on the digital grids corresponded to nearest larger integer of 100 divided by the number of photographs obtained along a particular transect. For example, at PRM 95.6 a total of 12 bed material sample photographs were obtained, so the sample point grid applied to each photograph had 9 sample points (Figure 4.5-1).

Each of the rectified photographs along a particular transect was imported into the GIS software ArcMap along with the appropriate digital sample point grid. The intermediate axis of bed material particles collocated with each sample point were then measured in units of millimeters for each sample photograph and recorded in a transect specific copy of the sample point grid shapefile. In order to ensure consistent measurements between multiple staff, rules for handling exceptions were defined and communicated to each staff measuring particles from the photographs. The resulting measurements were imported into an Excel spreadsheet file and sorted into ½ phi size bins corresponding to the size categories previously used for the summer field period gradation analysis. In addition to the grain size distribution obtained from the percentage of sample points categorized in each ½ phi size bin, the D_{16}, D_{50}, D_{84}, and D_{90} grain sizes were computed for each sample transect.

4.6. Quality Control

The Fluvial Geomorphology Modeling Task Lead provided training to the hydraulic engineers/geomorphologists and the GIS analysts to ensure appropriate identification and application of the classification categories. Hydraulic engineers/geomorphologists reviewed the sample photographs to determine usefulness for further processing. All sample videos were reviewed in the field and field notes were logged regarding initial review and possible issues associated with individual sample bed material photographs. The hydraulic engineers/geomorphologists frequently consulted with the Geomorphology Program Lead, the Geomorphology Study Task Lead and the Fluvial Geomorphology Modeling Task Lead on application of the measurement procedure and for advice when challenging measurements were identified. Completed bed material gradations for each transect location were reviewed by senior hydraulic engineers/geomorphologists and the Fluvial Geomorphology Modeling Task Lead.

5. RESULTS

The Upper, Middle, and Lower River Segment winter bed material sampling as well as the Chulitna and Talkeetna Rivers sampling provides valuable grain size distribution data that were otherwise missing from the overall Geomorphology studies (Study 6.5 and Study 6.6). Data had been acquired for shallow/wadeable water areas and exposed areas of main channel gravel bars, tributaries, and heads of islands. However, bed material gradations had not previously been sampled and quantified for the deepest portions of the main river channel.

5.1. Upper Susitna River Segment

The Upper Susitna River main channel bed material was sampled at five locations (Figure 5.1-1), including:

- PRM 195.6,
- PRM 214,
- PRM 230.1,
- PRM 240, and
- PRM 253.6.

These locations were selected in order to understand main channel bed material grain size distribution, upstream of the proposed dam location (PRM 195.6), near the mid-point of the Upper River Geomorphic Reach 4 (PRM 214), approximately 5 miles downstream of the Oshetna River confluence and at the upper end of the proposed reservoir (PRM 230.1), approximately 5 miles upstream of the Oshetna River confluence and above the proposed reservoir (PRM 240), and within the uppermost geomorphic study reach (PRM 253.6). The combined results for the five bed material gradation curves are shown on Figure 5.1-2, and gradation curves for each individual transect are shown on Figures A.1 through A.5 of Appendix A. The largest percentage of coarse bed material occurred at PRM 230.1, downstream of the Oshetna River confluence. The largest percentage of the finest bed material occurred at PRM 253.6, within the uppermost geomorphic study reach, UR-1.

The average median particle diameter, or D_{50} grain size, for the Upper River transects is 119 mm and equivalent to small cobbles. The minimum computed D_{50} grain size for the Upper River transects is 62 mm at PRM 195.6, upstream of the proposed dam location. The maximum D_{50} grain size is 171 mm at PRM 230.1, downstream of the Oshetna River confluence. The range of D_{50} values for the Upper River transects sampled indicates that the median bed material of the Upper River is comprised of very coarse gravels to large cobbles. A summary of the descriptor distribution values is provided in Table 5.1-1. A complete tabulation of the gradations for the Upper River winter bed material samples is provided in Appendix B Table B.1.

5.2. Middle Susitna River Segment

The Middle Susitna River main channel bed material was sampled at 12 locations (Figure 5.2-1). Each sample location was processed following the methods detailed in Section 4. The 12 resulting bed material gradation curves for the Middle River are shown in Figure 5.2-2. Gradation curves for each individual transect are shown in Appendix A on Figures A.6 through A.20. For the Middle River, the largest percentage of coarse bed material occurred at PRM 184.3, downstream of the proposed dam location and within geomorphic reach MR-2. The location with the smallest bed material for the Middle River segment occurred at PRM 113.9, located in geomorphic reach MR-7 and Focus Area 113. Grain sizes measured at PRM 113.9 were smaller than other transects along the Middle River, and when compared to the next largest size descriptor value for a transect in the Middle River were:

- Smaller by 3% for the D_{16} grain size,
- Smaller by 18% for the D_{50} grain size,
- Smaller by 40% for the D_{84} grain size, and
- Smaller by 51% for the D_{90} grain size.

The average median particle diameter, or D_{50} grain size, for the Middle River transects is 114 mm and equivalent to small cobbles. The minimum computed D_{50} grain size for the Middle

River transects is 46 mm at PRM 113.9, located in geomorphic reach MR-7 and Focus Area 113. The maximum D_{50} grain size for the Middle River is 385 mm at PRM 184.3, located in geomorphic reach MR-2, and is greater than the Middle River averaged D_{84} and D_{90} values of 269 mm and 323 mm, respectively. Averaging the median grain size for the Middle River transects excluding PRM 184.3 results in an average D_{50} value of 90 mm. The range of D_{50} values for the Middle River transects, excluding PRM 184.3, sampled indicates that the median bed material of the Middle River is comprised of very coarse gravels to small cobbles. A summary of the descriptor distribution values is provided in Table 5.1-1. A complete tabulation of the gradations for the Middle River winter bed material samples is provided in Appendix B Table B.2.

5.3. Chulitna River and Talkeetna River Transects

Two locations were sample on each of the Chulitna River and Talkeetna River (Figure 5.2-1). Each sample location was processed following the methods detailed in Section 4 with the exception of the samples obtained for the Chulitna River at river mile 7.2. This sample transect was not processed since the number of photographic samples was low, at only 7 photographs, and had low image quality due to apparent turbidity and resulting low light (Figure 5.3-1). This presented a more difficult transect to process and the potential for a skewed gradation due to the low number of sample photographs. Therefore, during the quality control review process the Fluvial Geomorphology Modeling Task Lead elected to discard this sample from further processing and determination of bed material gradation. The combined gradation curves for the one processed transect from the Chulitna River and the two processed transects from the Talkeetna River are shown in Figure 5.3-2.

The median particle diameter, or D_{50} grain size, for the processed data from the transect at Chulitna River mile 9.7 is 63.7 mm and equivalent to very coarse gravels. The D_{50} grain sizes for the two Talkeetna River transects, at river mile 4.1 and river mile 2, were 70.7 mm and 33.2 mm respectively. A summary of the descriptor distribution values for the Chulitna River and Talkeetna River is provided in Table 5.1-1. A complete tabulation of the gradations for the Chulitna River and Talkeetna River samples in Table B.3.

5.4. Lower Susitna River Segment

The Lower Susitna River main channel bed material was sampled at six locations (Figure 5.4-1), including:

- PRM 95.6,
- PRM 75,
- PRM 57,
- PRM 39.2,
- PRM 29.9, and
- PRM 21.8.

Samples obtained for the lowest three PRM's, PRM 39.2, PRM 29.9, and PRM 21.8, contained fractions of material finer than the average 8mm particle size that could be resolved in the photographic samples and corresponding bed material comprised of fine gravels to sands.

Additionally, difficult sample photograph acquisition occurred at PRM 29.9 and 21.8 for reasons including high turbidity, high water velocities, and deep main channel sections. Due to poor image quality, the Fluvial Geomorphology Modeling Task Lead elected to discard the sample photographs from PRM 21.8 from the rectification process and determination of bed material gradation; however, qualitative inspection of the better photographs at this location indicate sand wave bed patterns (Figure 5.4-2). At PRM 39.2, a total of 108 sample grid points were inspected for particle grain size on the rectified photographs and 93, or 86% of the sample transect, of the particles located at sample grid points were determined to be finer than 8 mm. Similarly, at PRM 29.9, 44 of the 53 particles, or 83%, inspected at sample grid point locations were determined to be finer than 8 mm. Due to the high percentage of fine bed material, particle size distributions and gradation statistics were not computed for PRM 39.2 or for PRM 29.9.

The three processed bed material gradation curves for the Lower River transect locations at PRM 95.6, PRM 75, and PRM 57, are shown together on Figure 5.4-3, and individually in Appendix A on Figures A.21 through A.23. The median bed material grain size, or D_{50}, for these locations indicates that the bed material is generally comprised of very coarse gravels to small cobbles. A summary of the descriptor distribution values is provided in Table 5.1-1. A complete tabulation of the gradations for the Lower River winter bed material samples is provided in Appendix B Table B.4.

6. DISCUSSION

6.1. Discussion of Results

An underwater video camera was used to acquire photographs of bed material in the deepest portions of the main channel along sample transects within the study area of the Upper, Middle, and Lower Susitna River, and also at two locations each on the Chulitna River and the Talkeetna River. Still-frame image files were extracted from the video files and rectified using photogrammetric processes in order to more accurately measure sediment particle grain sizes. The particle sizes were measured at standardized sample grid point locations on each rectified sample photograph acquired along a transect. The particle sizes were categorized into ½ phi sized bins in order to determine grain size distributions and size descriptors, including the statistical sizes for the D_{16}, D_{50}, D_{84}, and D_{90}, for each transect (previously presented Table 5.1-1).

The results indicate that the median main channel bed material upstream of PRM 39.2 is comprised of very coarse gravels to small and large cobbles. Excluding, the larger gradation data obtained from PRM 184.3 which had a D_{50} value of 385 mm, the average D_{50} value for the Susitna River sample transects is 92 mm, and the range of D_{50} values vary from 35.7 mm and 171 mm. The results for the lowermost transects, including PRM 39.2, 29.9, and 21.8, indicated large amounts of sand present on the main channel bed. The data determined from this field and post-processing effort is being incorporated into the 1-D and 2-D bed evolution model development and analysis described in Study 6.6 ISR Section 7.2.1.1.5, and further analyses will be presented in subsequent technical memorandums (Tetra Tech 2014b).

Comparing the main channel data collected and reported in this technical memorandum with the bar head data presented in Study 6.6 ISR Part A – Appendix A indicates the presence of much coarser bed material in the main channel of the Middle River than the bar heads. Thus, bar head samples are not representative of the bed material in the deepest portions of the main channel in the Middle River. For the Middle River, the average median grain size for the main channel is a single ½ phi size larger than for the bar heads, with average D_{50} values of 83.2 mm for the main channel and 59.0 mm for the bar heads (Table 6.1-1). Additionally, the evaluation of size descriptors for the hypothesized potential lag deposit locations indicated similarly sized bed material at potential lag deposit locations and other nearby transect locations (Table 6.1-2). The general coarsening of particle sizes and difference between deepest portion of the main channel sampled during the winter effort and bar head samples collected during the summer effort is illustrated for the Middle River locations is shown in Figure 6.1-1.

However, comparison of the Lower River main channel data, for which gradations were computed, with the bar head data indicates that there are similarities between some of the locations. For the Lower River, the two downstream most analyzed winter samples, for PRM 57 (geomorphic reach LR-3) and PRM 75 (geomorphic reach LR-2), are similar in size to those of the summer samples. Specifically, the D_{50} value for the main channel samples at PRM 75 is 35.7 mm and at PRM 75 is 38.8 mm, and the average D_{50} value for the Lower River at bar heads is 33.5 mm (Table 6.1-3). The D_{50} value of PRM 95.6 (geomorphic reach LR-1) is 92.5 mm, which is more similar to that of the Middle River main channel average D_{50} value of 86.2 mm. Thus, for the lower portion of the Lower River, gradations for bar head samples are informative of main channel bed material and bar head gradations were used to define the 1-D model inputs.

6.2. Difficulties in Gradation Determination Due to Field Site Condition Impacts on Bed Material Sample Photographs Acquired

Quality control and sample review played a critical role in assuring the usefulness of individual sample photographs and accuracy of post-processing methods used to determine the bed material gradations and size descriptors presented in this technical memorandum. Rectification by photogrammetric methods and development of measurement techniques that were consistently followed by sample processing staff helped to reduce the likelihood and magnitude of errors introduced by photographic distortion and operator bias. However, difficult conditions were present during the field acquisition of photographs, which at times included high turbidity, large amounts of frazil ice, deep flow depths, high velocities, large amounts of sand bed material, and the presence of possible anchor ice or other unexplained material observed on the river bed. These conditions could lead to degradation of photographic clarity and the ability to discriminate individual particle edges, smaller diameter particles that were shadowed from visibility by larger particles, and vibrations or bending with the handle sections the camera was mounted to causing imperfect vertical alignment.

The influence from a single image that may be negatively impacted for post-processing due to difficult field conditions is partially alleviated by the method applied to sample selected grid point locations for each of the rectified sample photographs. Even in cases where the Fluvial Geomorphology Task Lead determined the conditions were not suitable for quantification of bed material gradations, the photographs still provide useful qualitative information on the bed composition. Previous attempts at sampling bed material in the deepest portions of the main channel have been unsuccessful. Overall the results of these efforts provided important input for the 1-D and 2-D bed evolution modeling that would otherwise have been estimated based on measurements made outside of the deepest portions of the main channel.

6.3. Conclusions and Recommendations Concerning 2015 Studies

Acquisition and processing of main channel bed material photographic samples during the 2013/14 study period was successful. The grain size distribution data obtained from this task are being incorporated into the 1-D and 2-D bed evolution modeling efforts (Tetra Tech 2014b). Favorable conditions during the 2013/14 winter field sampling period allowed for the acquisition of more transects that originally projected for the period. In fact, each transect location identified for sampling was obtained during the 2013/14 period and no additional wintertime main channel bed material samples are needed or scheduled for acquisition during the 2014/15 wintertime period. The 2013/2014 winter bed sampling provides the data originally planned for collection over two winter periods. As this data includes the Middle and Lower Susitna River Segments as well as samples in the Chulitna and Talkeetna Rivers and is adequate for the intended bed evolution modeling. No additional winter bed material sampling is recommended.

7. REFERENCES

Tetra Tech. 2013. Field Assessment of Underwater Camera Pilot Test for Sediment Grain Size Distribution. Field Report. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2014a. Geomorphic Reach Delineation and Characterization, Upper, Middle and Lower Susitna River Segments. Susitna-Watana Hydroelectric Project. Updated Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2014b. One-Dimensional Bed Evolution Model Development and Decision Point. Susitna-Watana Hydroelectric Project. 2014 Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

8. TABLES

Table 4.1-1. Through ice bed material sample transect details collected during the winter 2014 geomorphic field effort.

River	PRM	Geomorphic Reach	Potential Lag Deposit	Focus Area	Number of Photographs Obtained	Camera Height Above Bed (feet)	Date of Sample
Susitna	21.8	LR-6		N.A.	17	Variable (2-3 feet)	March 26, 2014
Susitna	29.9	LR-5		N.A.	8	2	March 24, 2014
Susitna	39.2	LR-4		N.A.	18	3	March 24, 2014
Susitna	57	LR-3		N.A.	14	2	March 26, 2014
Susitna	75	LR-2		N.A.	20	2	March 27, 2014
Susitna	95.6	LR-1		N.A.	12	4	March 20, 2014
Susitna	104.1	MR-8		N.A.	11	3	March 19, 2014
Susitna	112	MR-7	X	N.A.	12	4	March 21, 2014
Susitna	113.9	MR-7		FA-113 (Oxbow 1)	10	4	March 21, 2014
Susitna	116	MR-7	X	FA-115 (Slough 6A)	13	3	March 21, 2014
Susitna	129	MR-6		FA-128 (Slough 8A)	16	4	March 23, 2014
Susitna	139.5	MR-6	X	FA-138 (Gold Creek)	16	4	March 23, 2014
Susitna	142.7	MR-6		FA-141 (Indian River)	16	3	March 22, 2014
Susitna	145.4	MR-6	X	FA-144 (Slough 21)	16	4	March 22, 2014
Susitna	152.1	MR-5		FA-151 (Portage Creek)	12	4	March 31, 2014
Susitna	174.4	MR-2		FA-173 (Stephan Lake Complex)	15	4	March 31, 2014
Susitna	184.3	MR-2		N.A.	14	4	April 1, 2014
Susitna	185.4	MR-1		FA-184 (Watana Dam)	19	3	April 1, 2014
Susitna	195.6	UR-6		N.A.	22	2	April 2, 2014
Susitna	214	UR-4		N.A.	12	2	April 4, 2014
Susitna	230.1	UR-3		N.A.	20	2	April 3, 2014
Susitna	240	UR-2		N.A.	17	2	April 3, 2014
Susitna	253.6	UR-1		N.A.	16	2	April 2, 2014
Chulitna	7.2	CH		N.A.	7	2	March 20, 2014
Chulitna	9.7	CH		N.A.	18	2	March 25, 2014
Talkeetna	2	TK		N.A.	16	2	March 20, 2014
Talkeetna	4.1	TK		N.A.	18	3	March 25, 2014

Table 5.1-1. Summary of winter bed material gradation.

River	PRM	D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)	Gr
Susitna	21.8	[1]	[1]	[1]	[1]	[1]
Susitna	29.9	[1]	[1]	[1]	[1]	[1]
Susitna	39.2	[1]	[1]	[1]	[1]	[1]
Susitna	57	21.1	38.8	71.4	81.4	1.8
Susitna	75	23.1	35.7	69.3	95.4	1.7
Susitna	95.6	35.9	92.5	175.8	202.4	2.2
Susitna	104.1	45.2	95.1	183.4	209.5	2.0
Susitna	112	31.6	56.1	124.7	174.0	2.0
Susitna	113.9	28.3	46.1	75.6	84.4	1.6
Susitna	116	46.4	92.1	211.5	240.7	2.1
Susitna	129	29.1	68.3	187.8	258.9	2.5
Susitna	139.5	47.1	102.1	235.7	289.0	2.2
Susitna	142.7	60.1	126.5	257.0	310.9	2.1
Susitna	145.4	34.7	79.2	304.0	390.8	3.1
Susitna	152.1	45.7	115.6	293.1	343.7	2.5
Susitna	174.4	42.1	96.6	283.4	357.3	2.6
Susitna	184.3	87.7	385.2	823.9	928.3	3.3
Susitna	185.4	39.6	109.1	245.4	283.6	2.5
Susitna	195.6	22.9	61.9	111.0	124.6	2.2
Susitna	214	27.4	91.1	228.7	279.3	2.9
Susitna	230.1	60.2	171.4	405.2	650.0	2.6
Susitna	240	43.6	162.1	342.5	396.6	2.9
Susitna	253.6	24.6	108.9	316.1	359.1	3.7
Chulitna	7.2	[1]	[1]	[1]	[1]	[1]
Chulitna	9.7	28.1	63.7	115.6	130.2	2.0
Talkeetna	2	15.6	33.1	87.0	106.6	2.4
Talkeetna	4.1	22.3	70.7	154.5	183.2	2.7

Notes:

Gradation and size descriptors not processed due to high percentage of sand present in bed material and/or low image quality.

Table 6.1-1. Average particle size descriptor statistics for Middle River sites sampled between PRM 103.9 and 145.5 for Main Channel and Bar Head samples.

Sample Location	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{90} (mm)
Main Channel	40.3	83.2	197.5	244.8
Bar Head	28.6	59.0	113.0	130.8

Table 6.1-2. Comparison of potential lag and non-lag deposit average particle size descriptor statistics at Main Channel sites in the Middle River.

Sample Location	D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)
Potential Lag Deposit[1]	40.0	82.4	219.0	273.6
Non-Lag Deposit[2]	41.7	90.3	199.4	241.5

Notes:

1 Average values for sample transects at PRM 112, PRM 116, PRM 139.5, and PRM 145.4.

2 Average values for sample transects at PRM 104.1, PRM 113.9, PRM 129, PRM 142.7, and PRM 152.1.

Table 6.1-3. Average particle size descriptor statistics for Main Channel and Bar Head sample sites on the Lower River.

Sample Location	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{90} (mm)
Main Channel	26.7	55.7	105.5	126.4
Bar Head	16.7	33.5	62.7	72.3

9. FIGURES

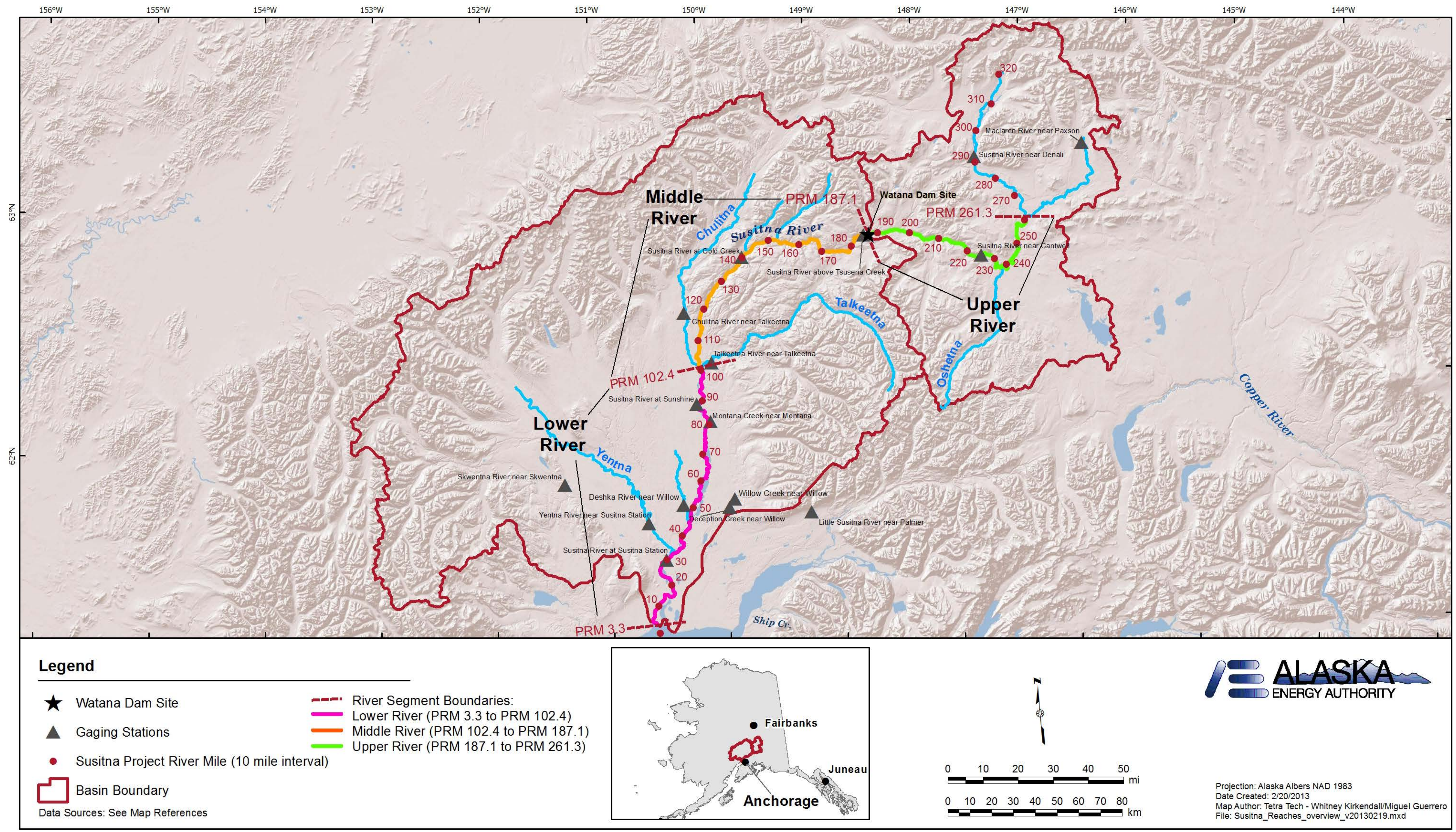

Figure 3.2-1. Susitna River Geomorphology study area and large-scale river segments.

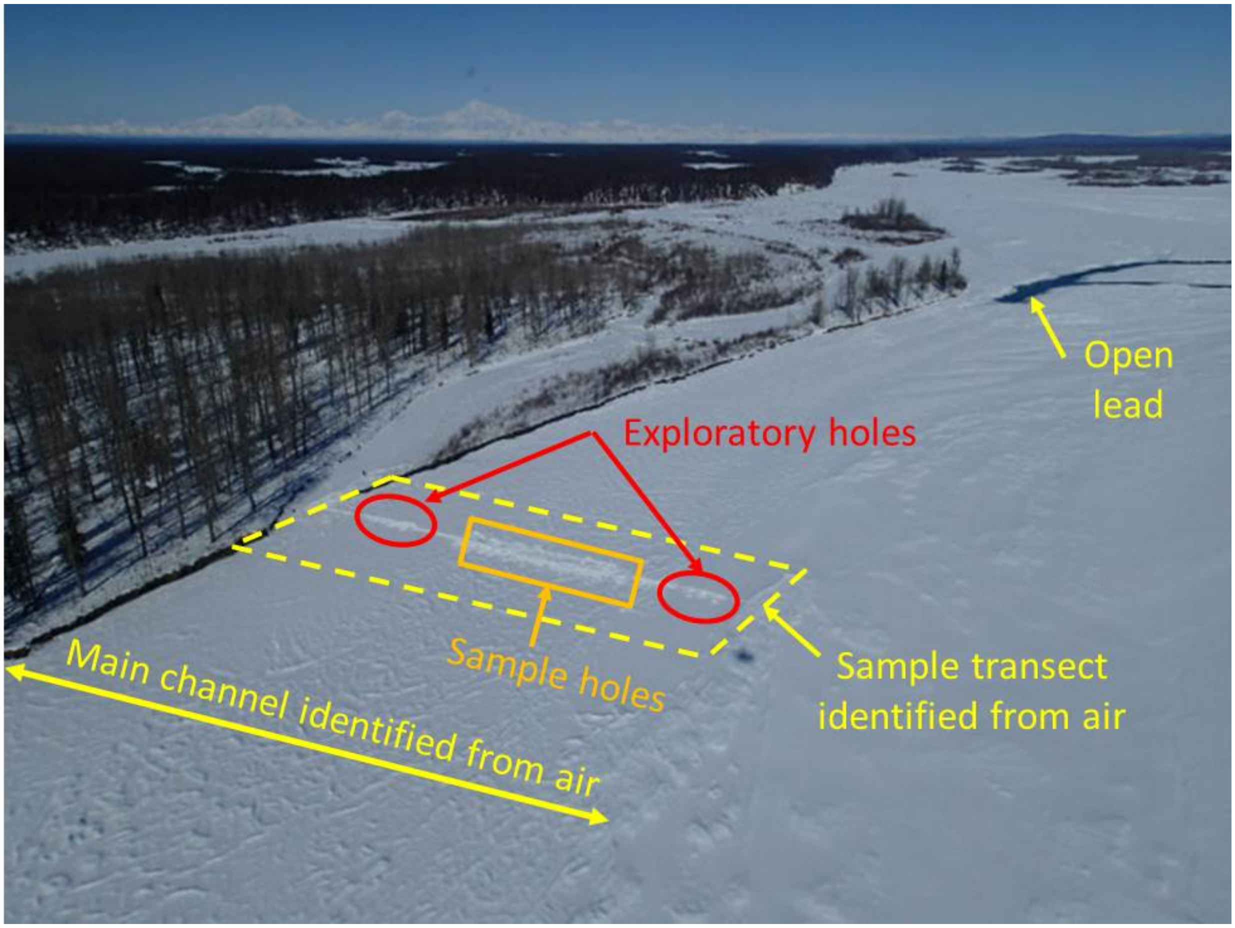

Figure 4.1-1. Typical sample transect and field evaluated factors for determination of sample holes shown for Susitna River PRM 75.

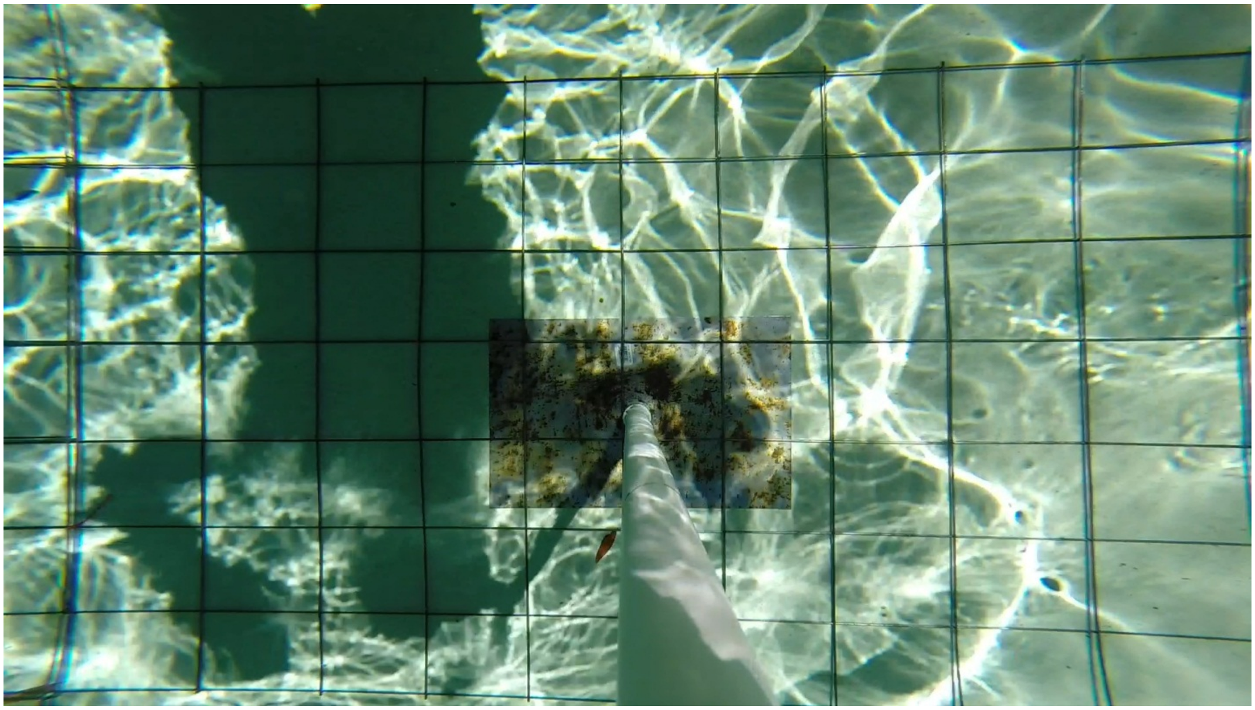

Figure 4.3-1. The calibration grid was photographed from different distances. Observe the stretching (distortion) of the square cells at the edges.

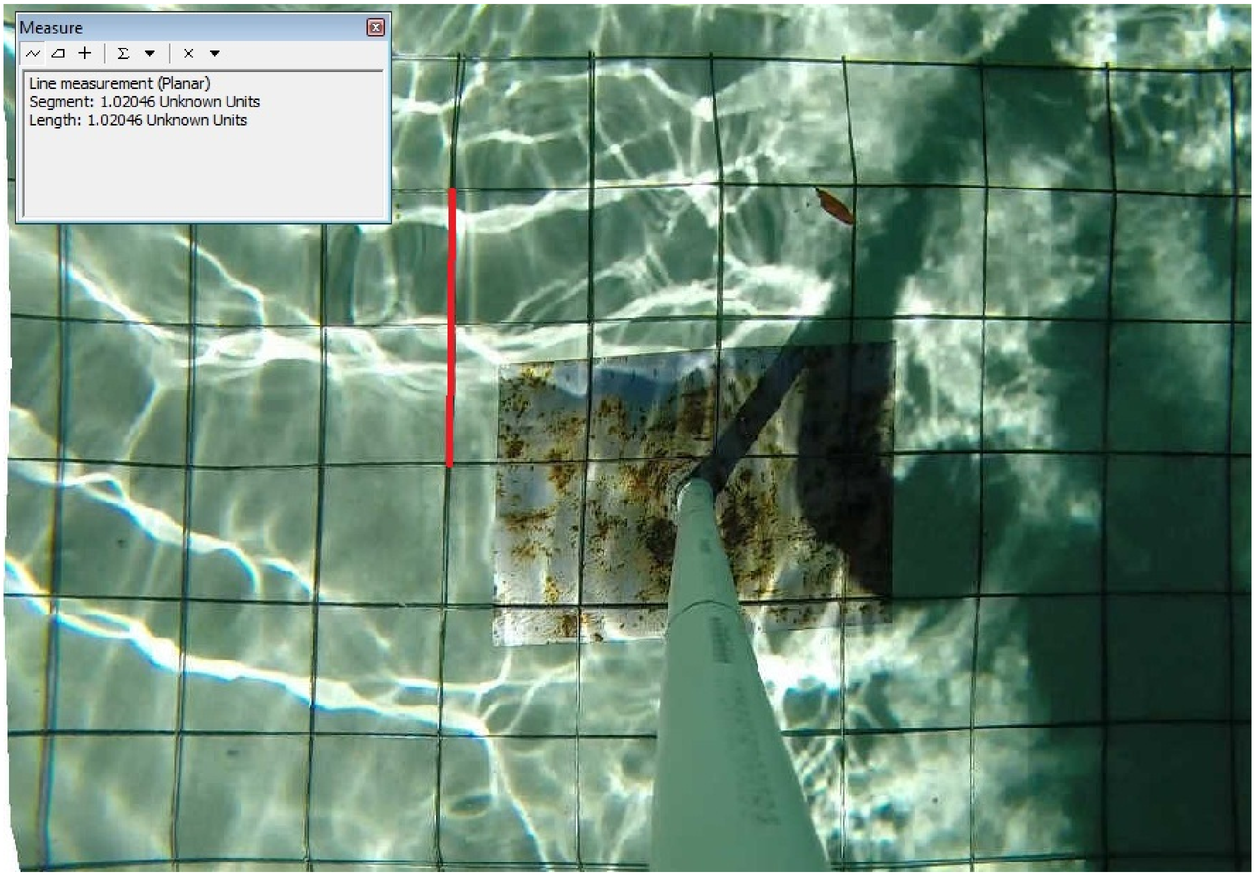

Figure 4.4-1. Reference grid taken from 3 ft, after rectification. The grid cells are now square and the 1 ft distance measures to 1.02 ft. Remaining distortions are larger towards the edges.

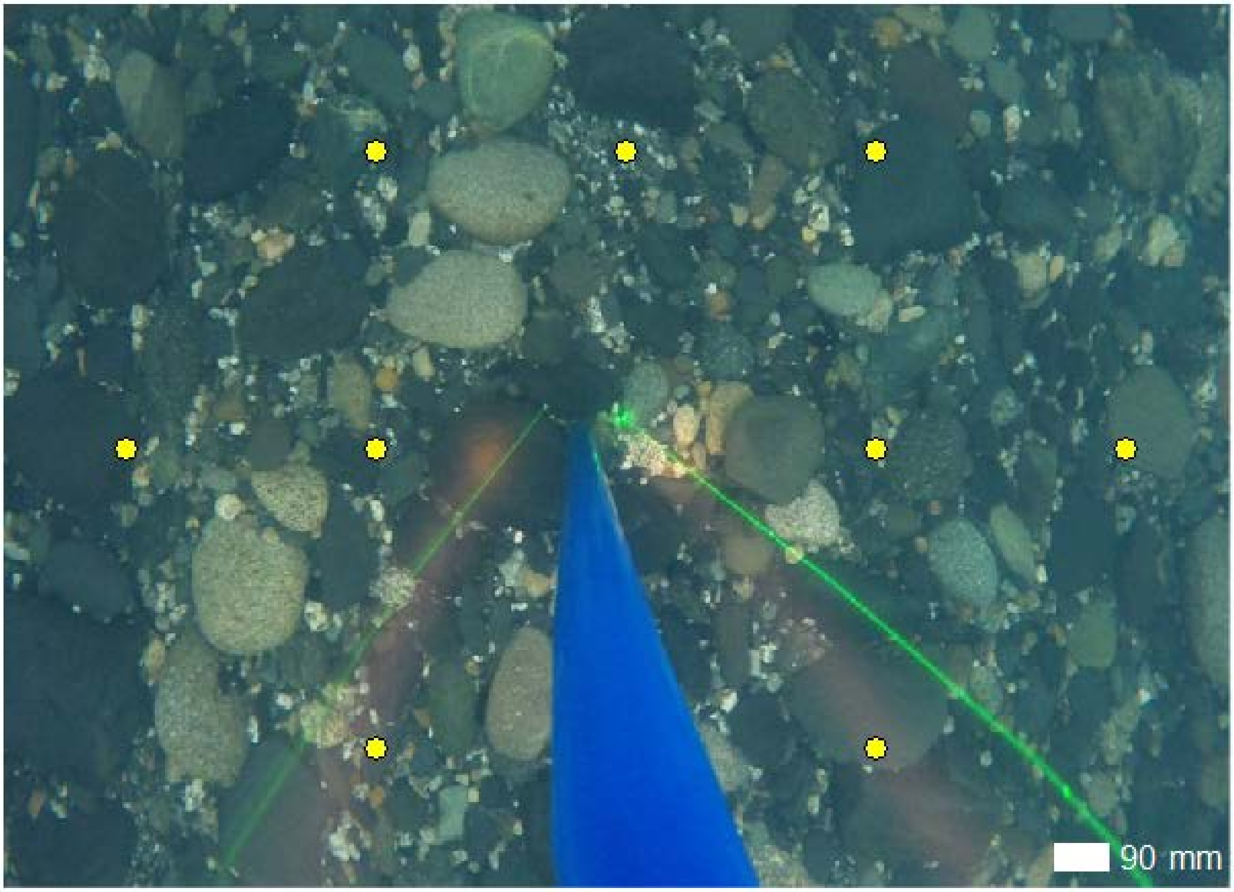

Figure 4.5-1. Rectified sample photograph of bed material at PRM 95.6 shown with digital sample point grid overlain as yellow points.

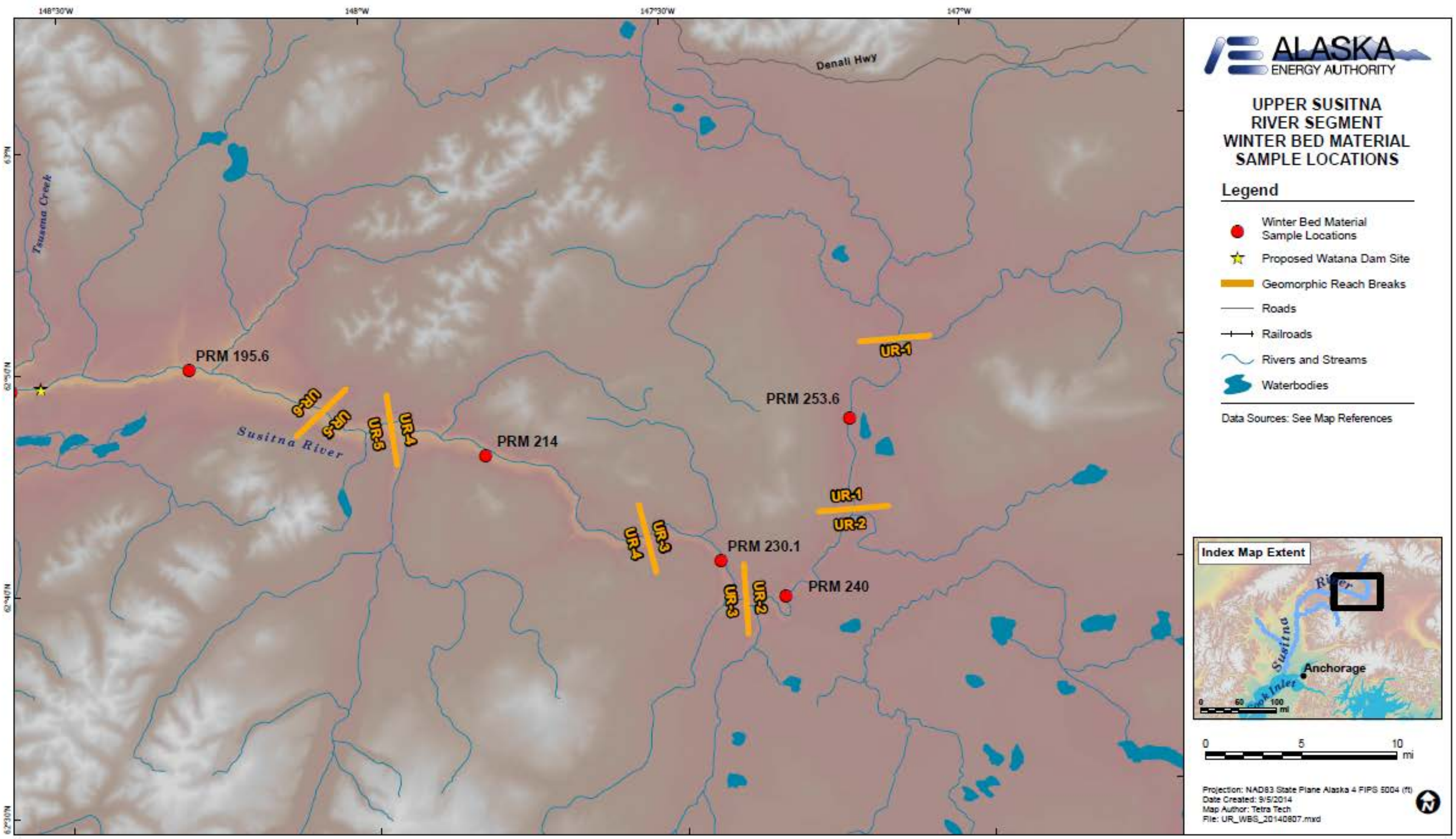

Figure 5.1-1. Upper Susitna River main channel bed material sample transect locations.

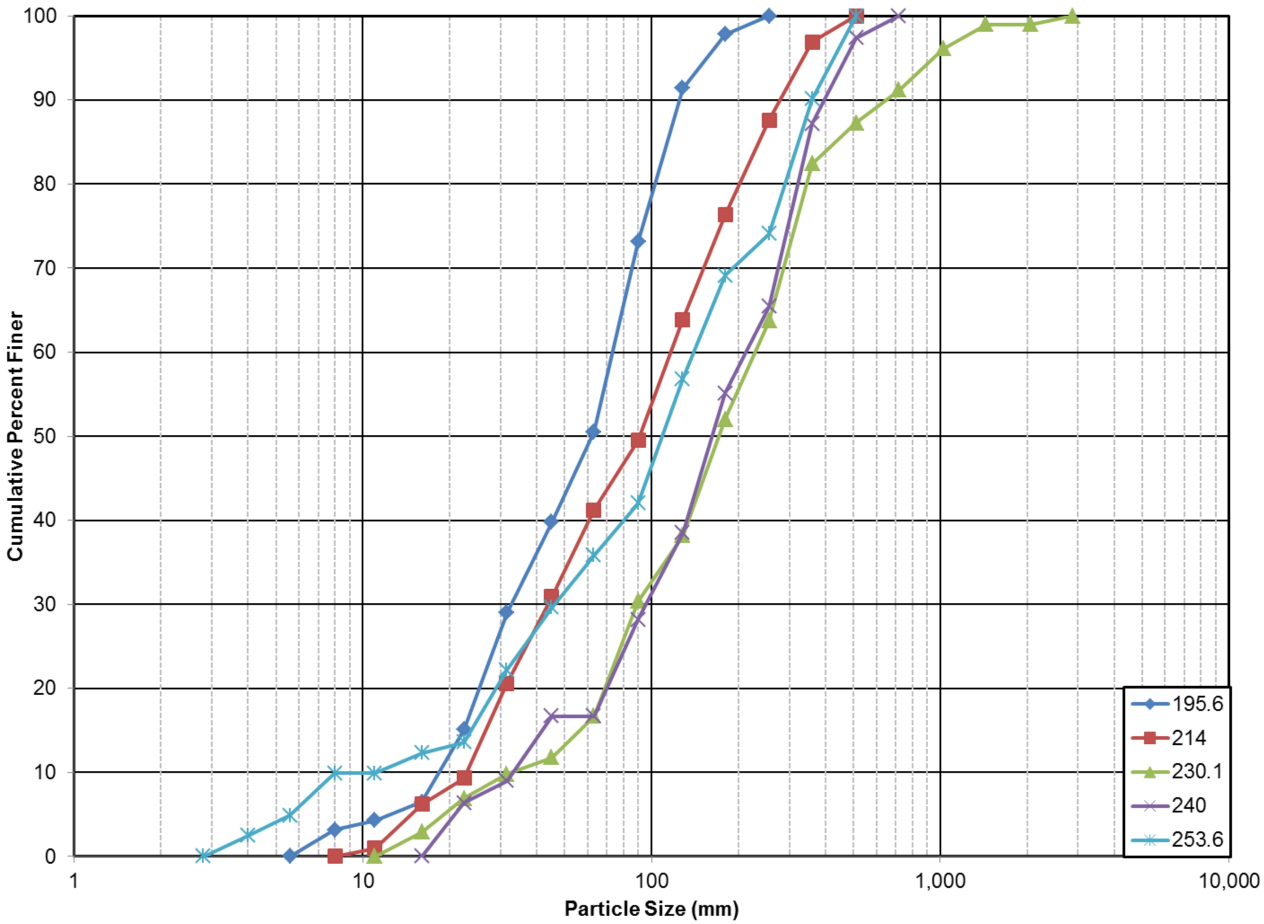

Figure 5.1-2. Upper Susitna River bed material gradation curves for PRM transects listed on figure.

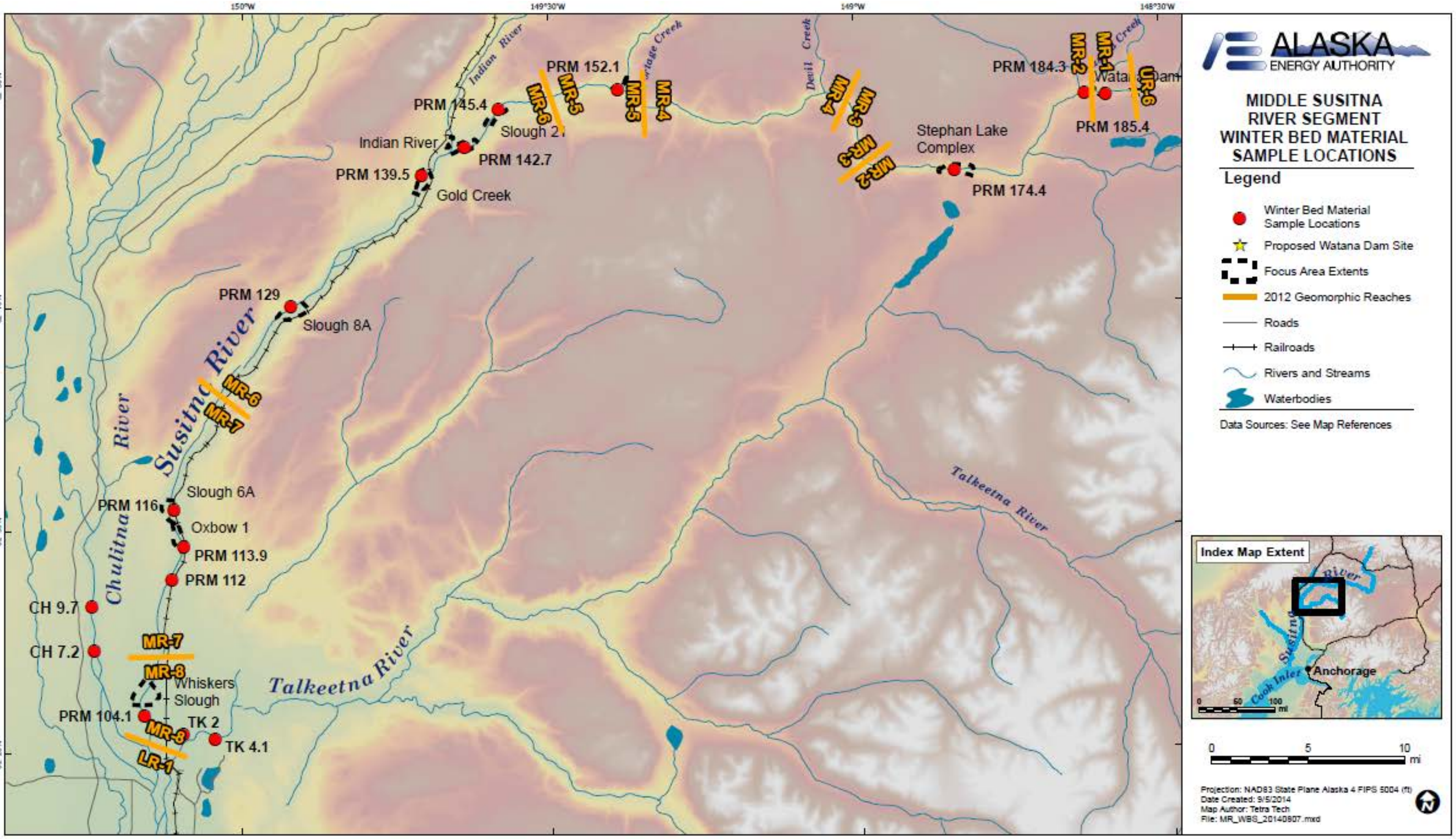

Figure 5.2-1. Middle Susitna River, Chulitna River, and Talkeetna River main channel bed material sample transect locations.

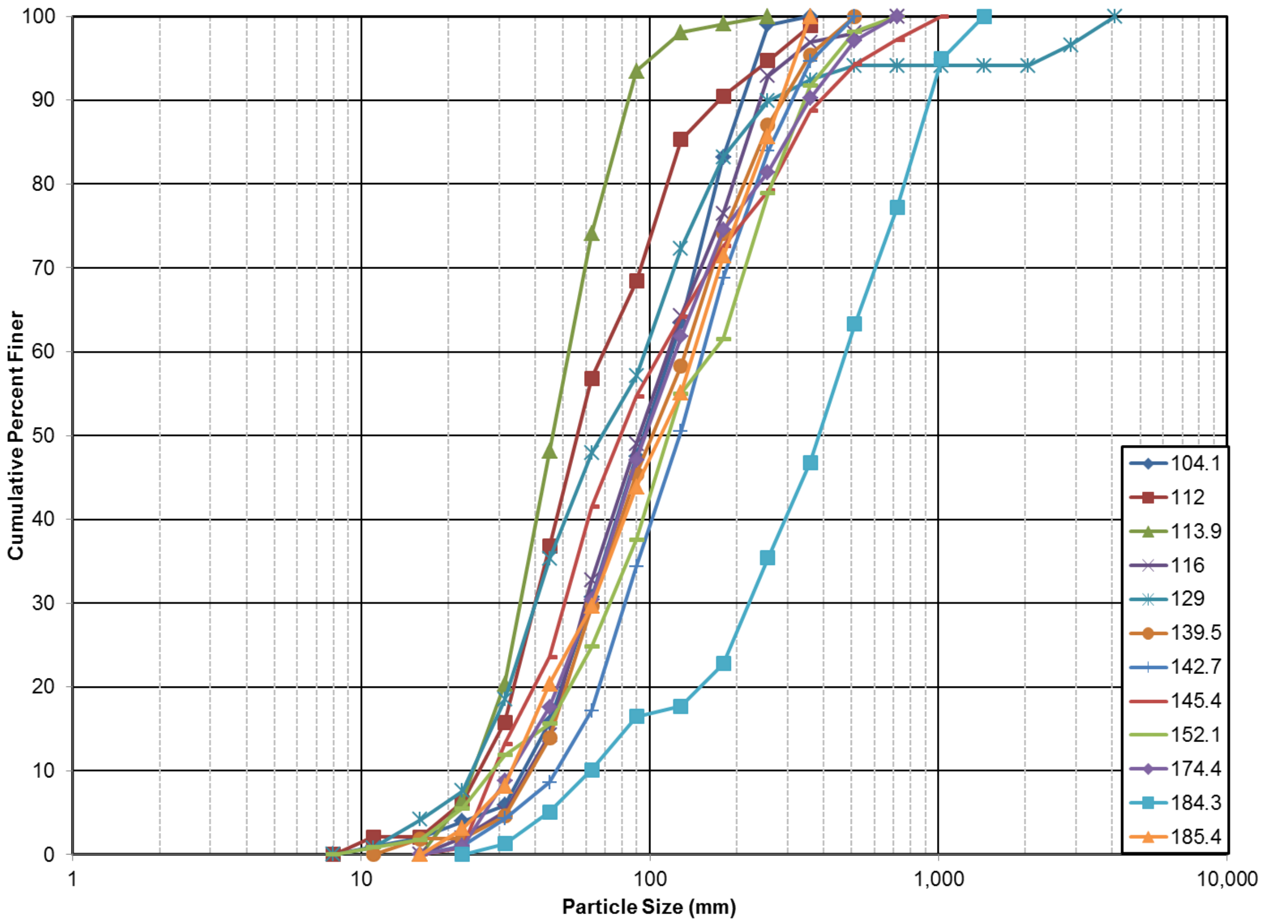

Figure 5.2-2. Middle Susitna River bed material gradation curves for PRM transects listed on figure.

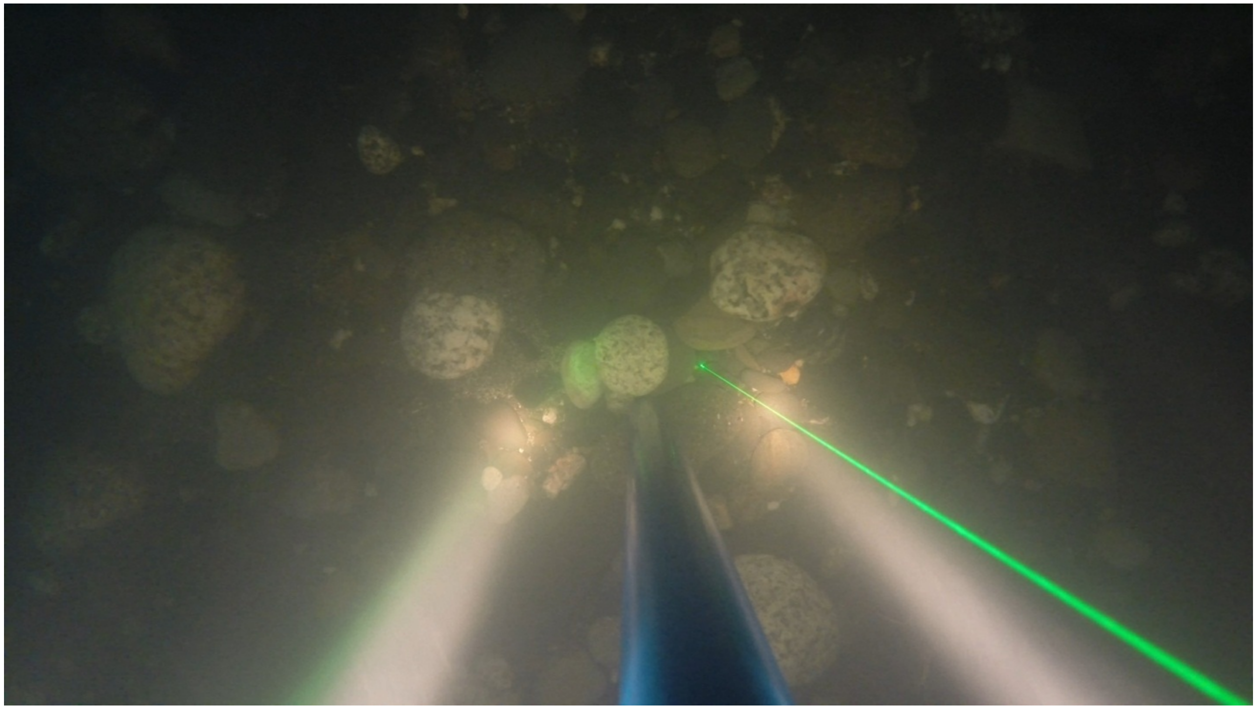

Figure 5.3-1. Unrectified sample photograph from transect at Chulitna River river mile 7.2, illustrating poor image quality for determination of bed material gradation due to turbidity and low light.

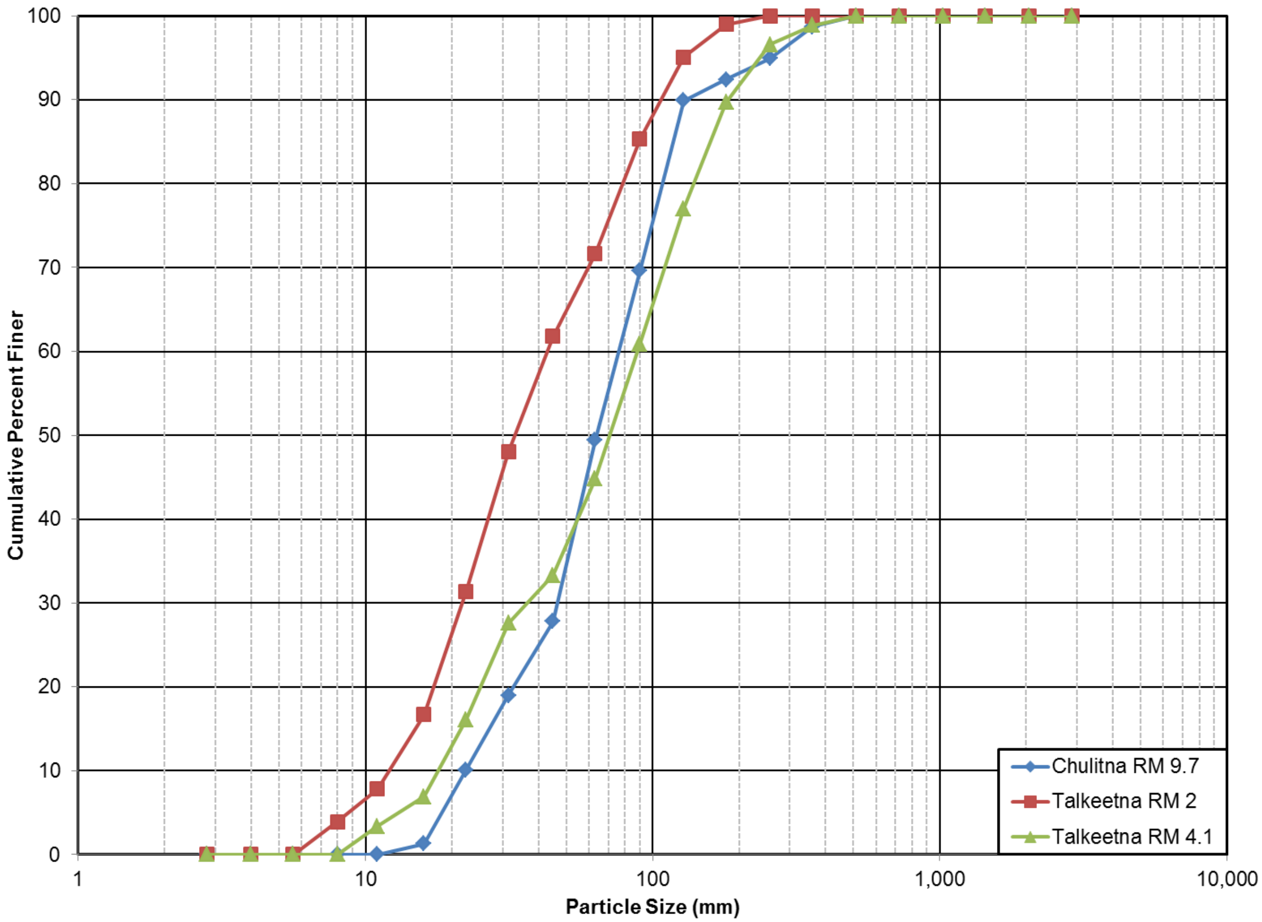

Figure 5.3-2. Chulitna River and Talkeetna River bed material gradation curves for river miles (RM) transects listed on figure.

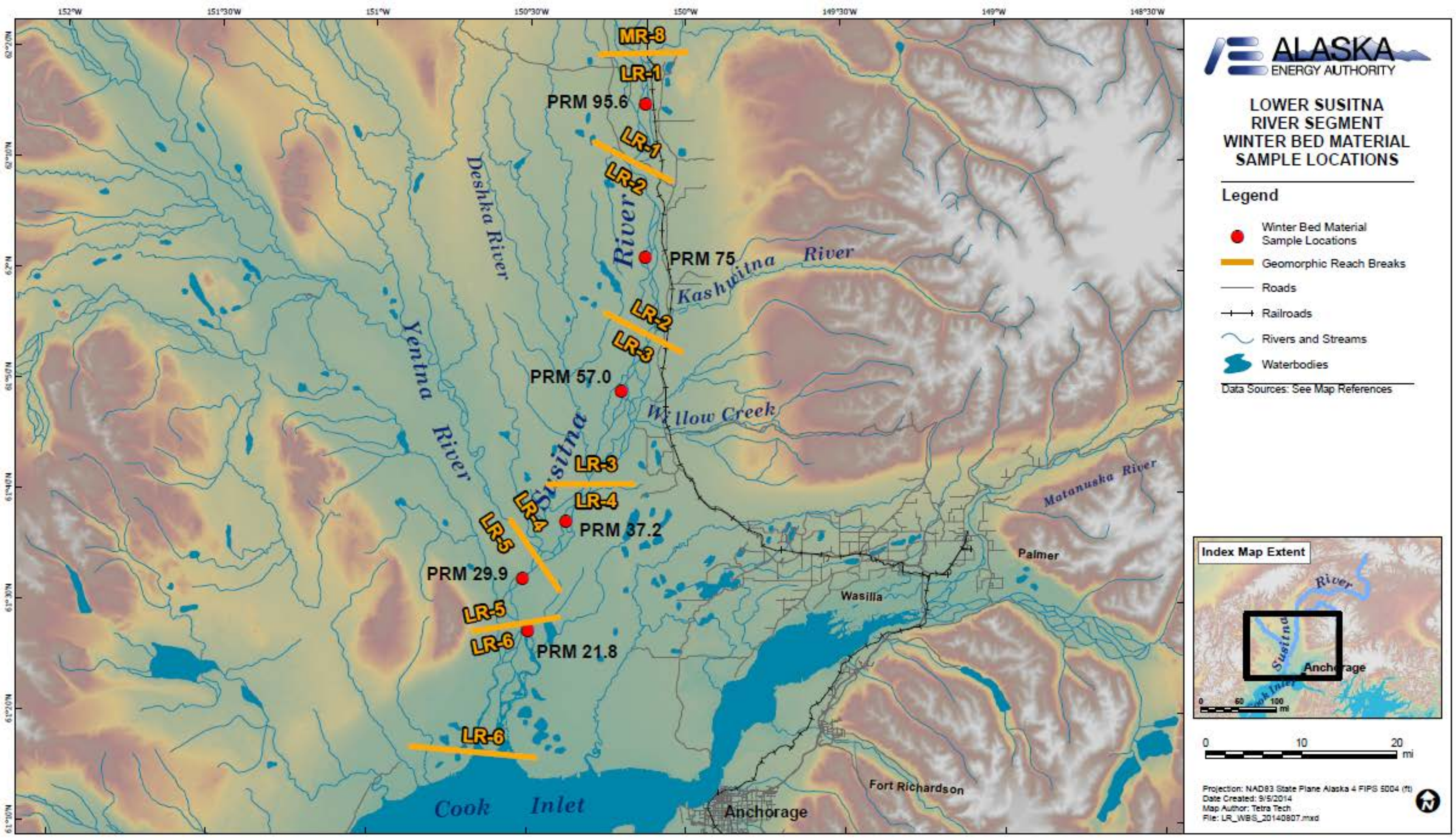

Figure 5.4-1. Lower Susitna River Segment main channel bed material sample transect locations.

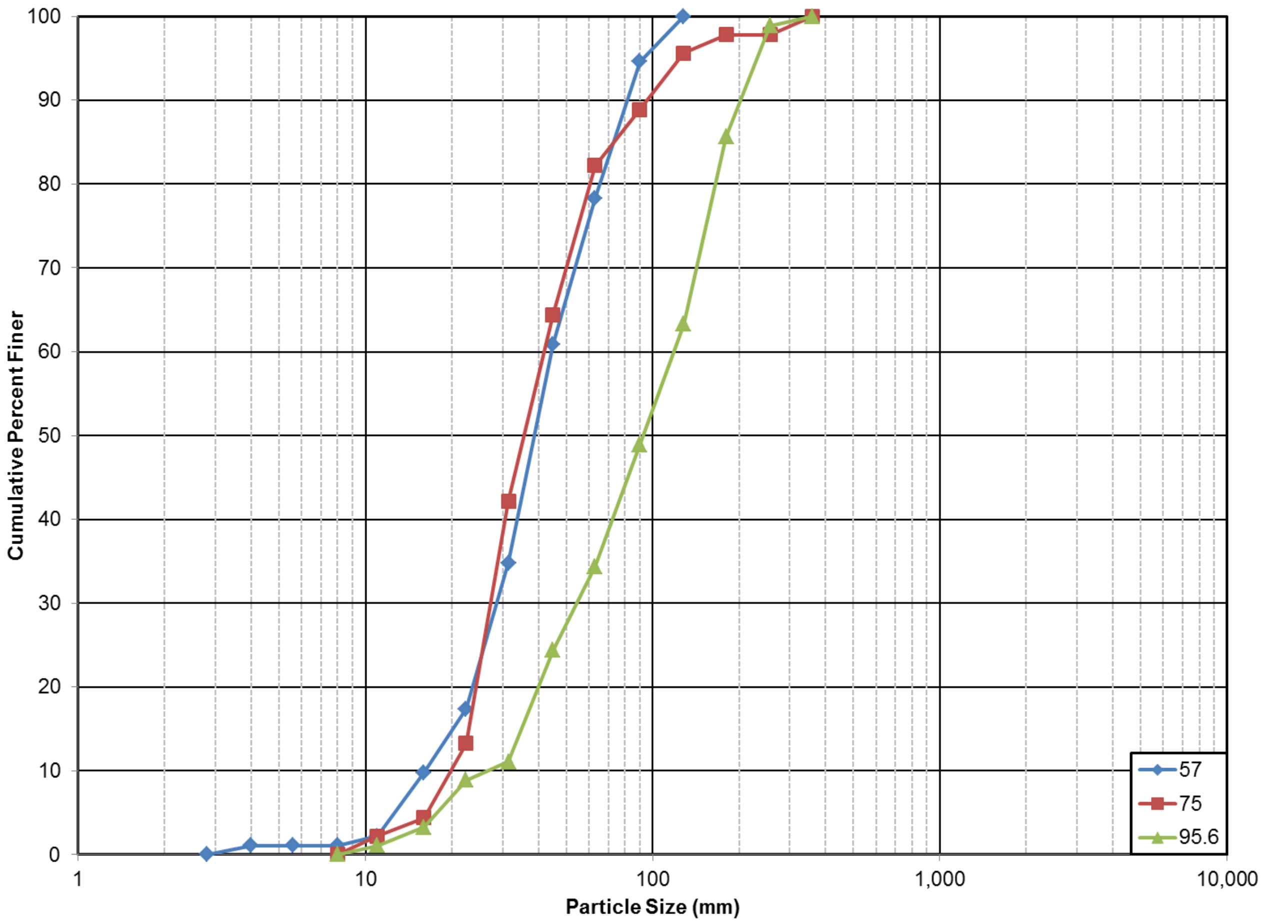

Figure 5.4-2. Lower Susitna River bed material gradation curves for PRM transects listed on figure.

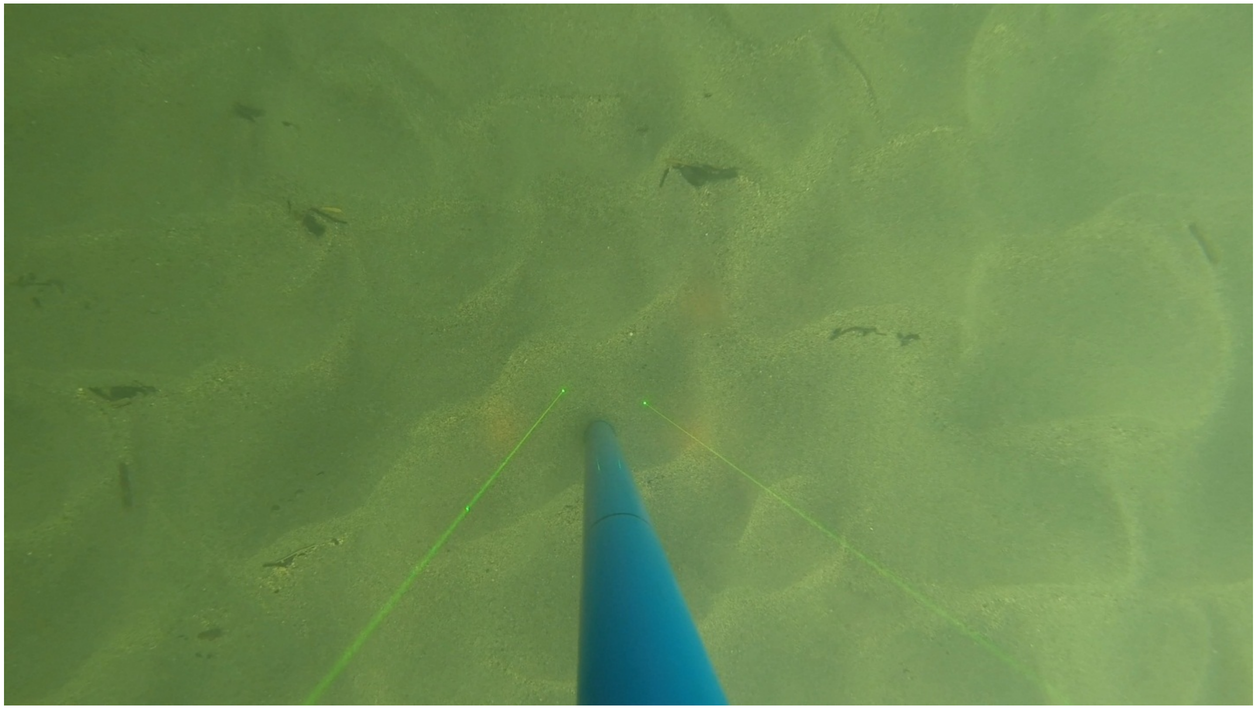

Figure 5.4-3. Unrectified sample photograph from PRM 21.8 showing sand wave bed patterns.

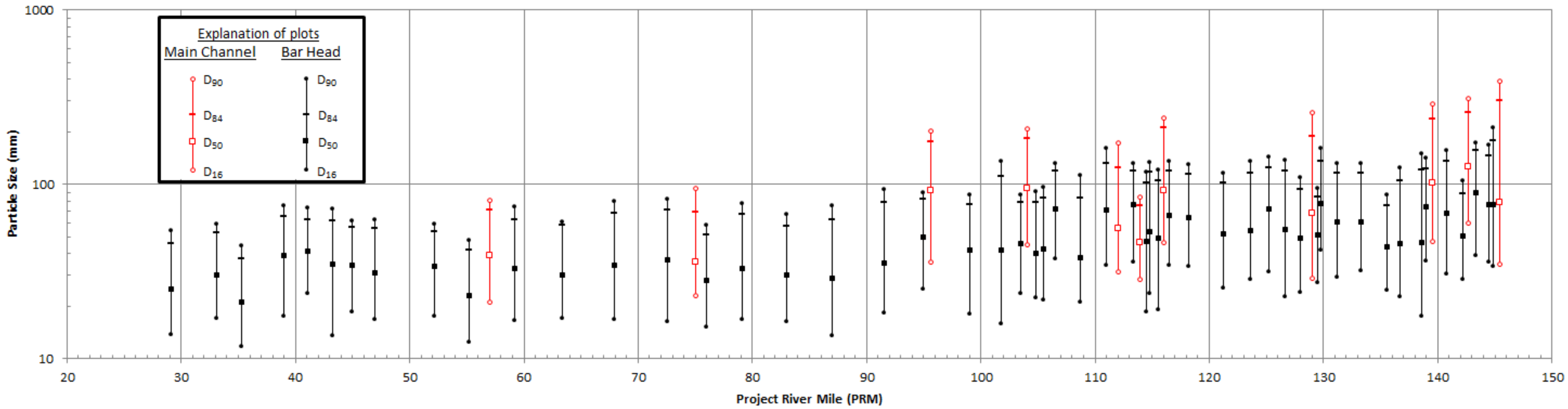

Figure 6.1-1. Size descriptors for Lower River and Middle River main channel and bar head sample locations.

APPENDIX A. MAIN CHANNEL TRANSECT GRADATION CURVES

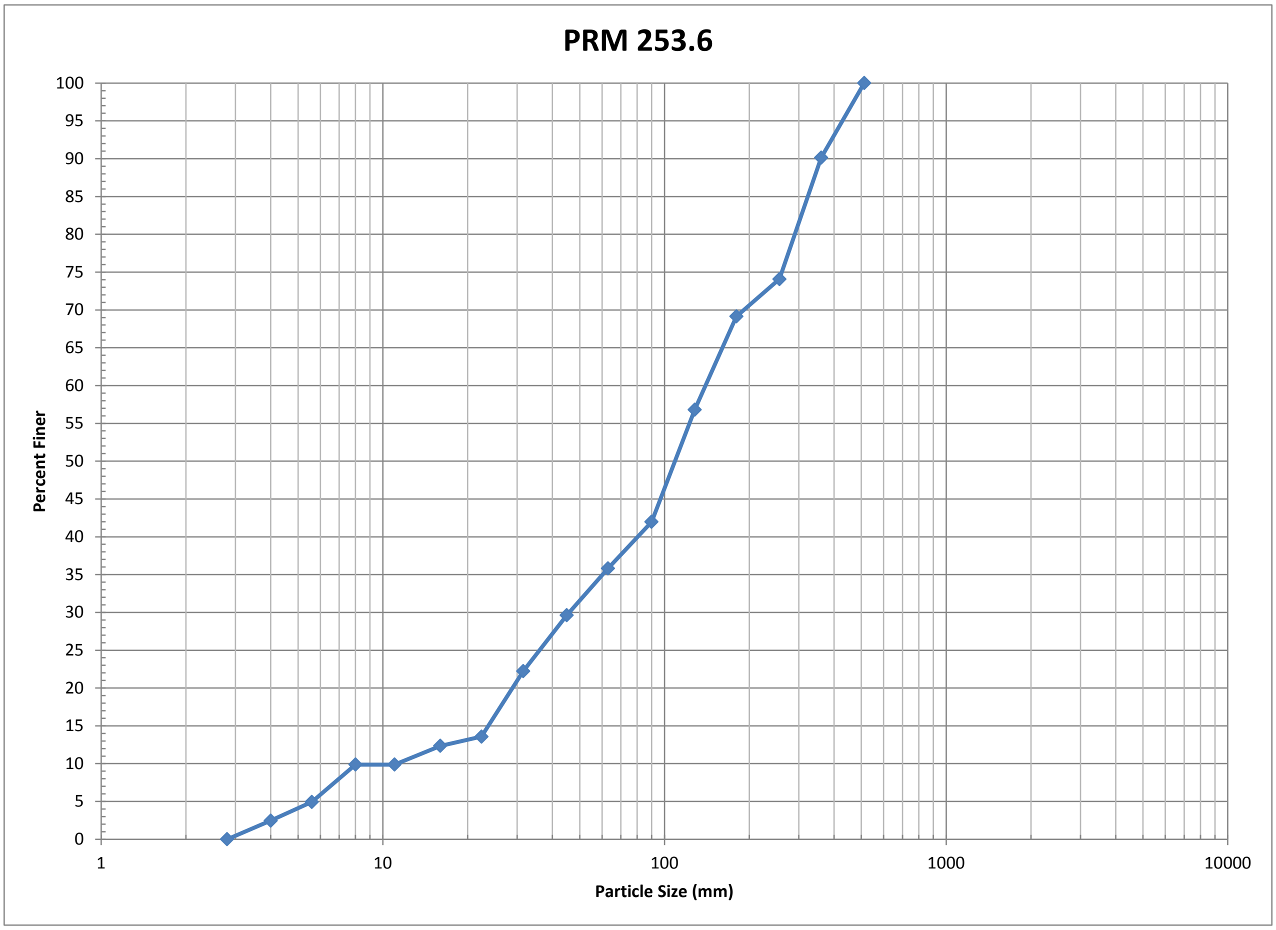

Figure A-1. Gradation curve for sample transect Susitna PRM 253.6.

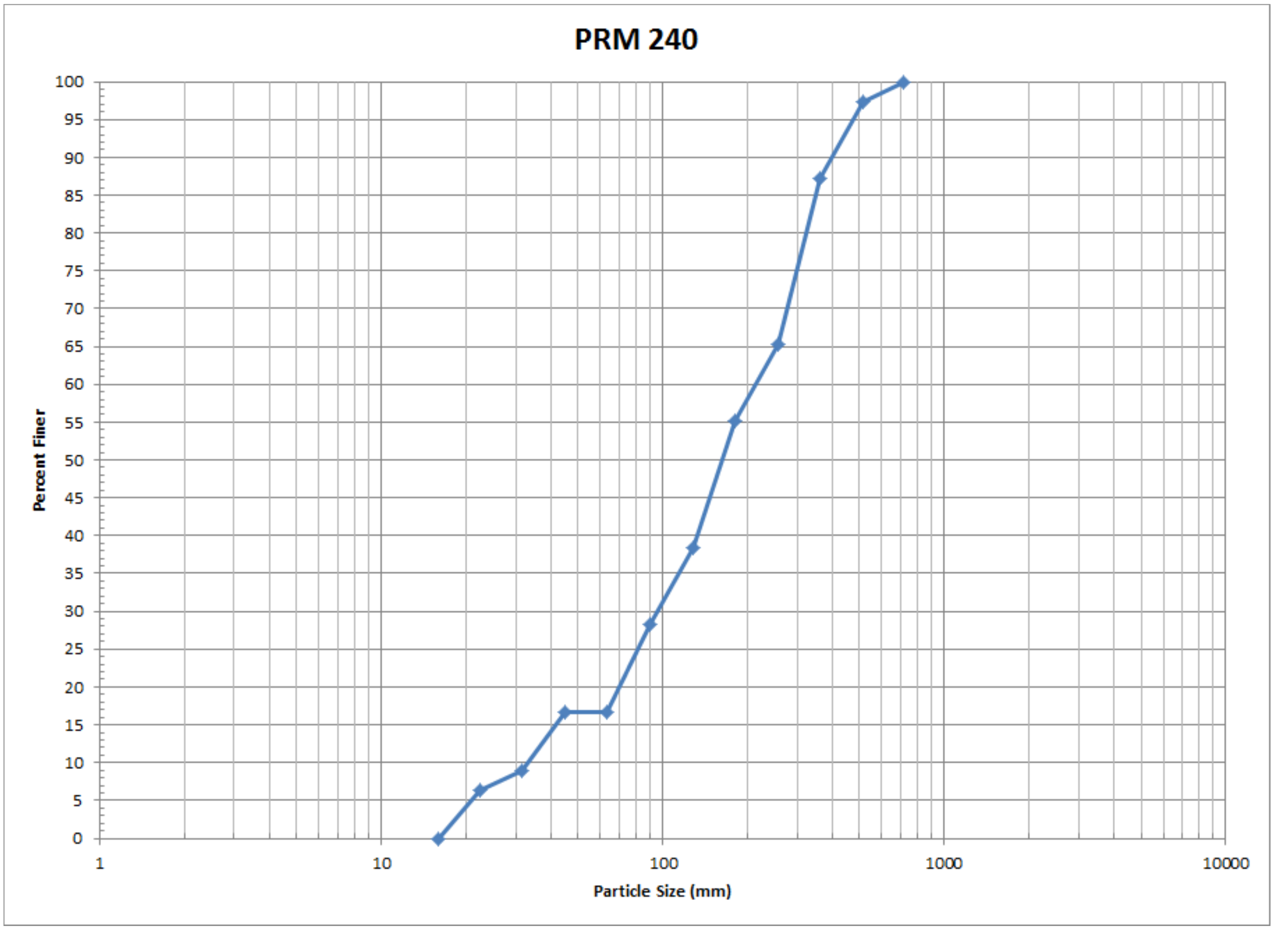

Figure A-2. Gradation curve for sample transect Susitna PRM 240.0.

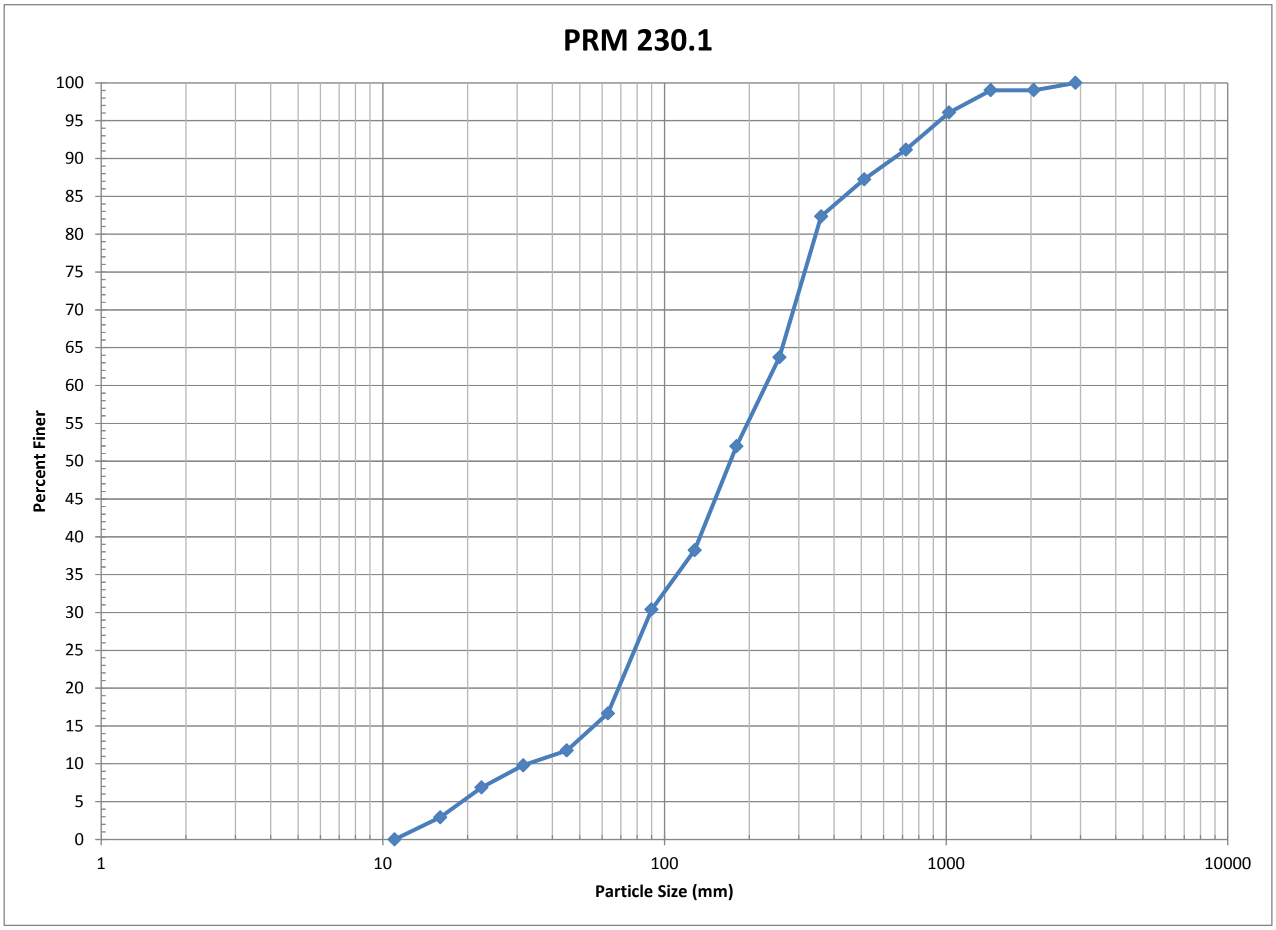

Figure A-3. Gradation curve for sample transect Susitna PRM 230.1.

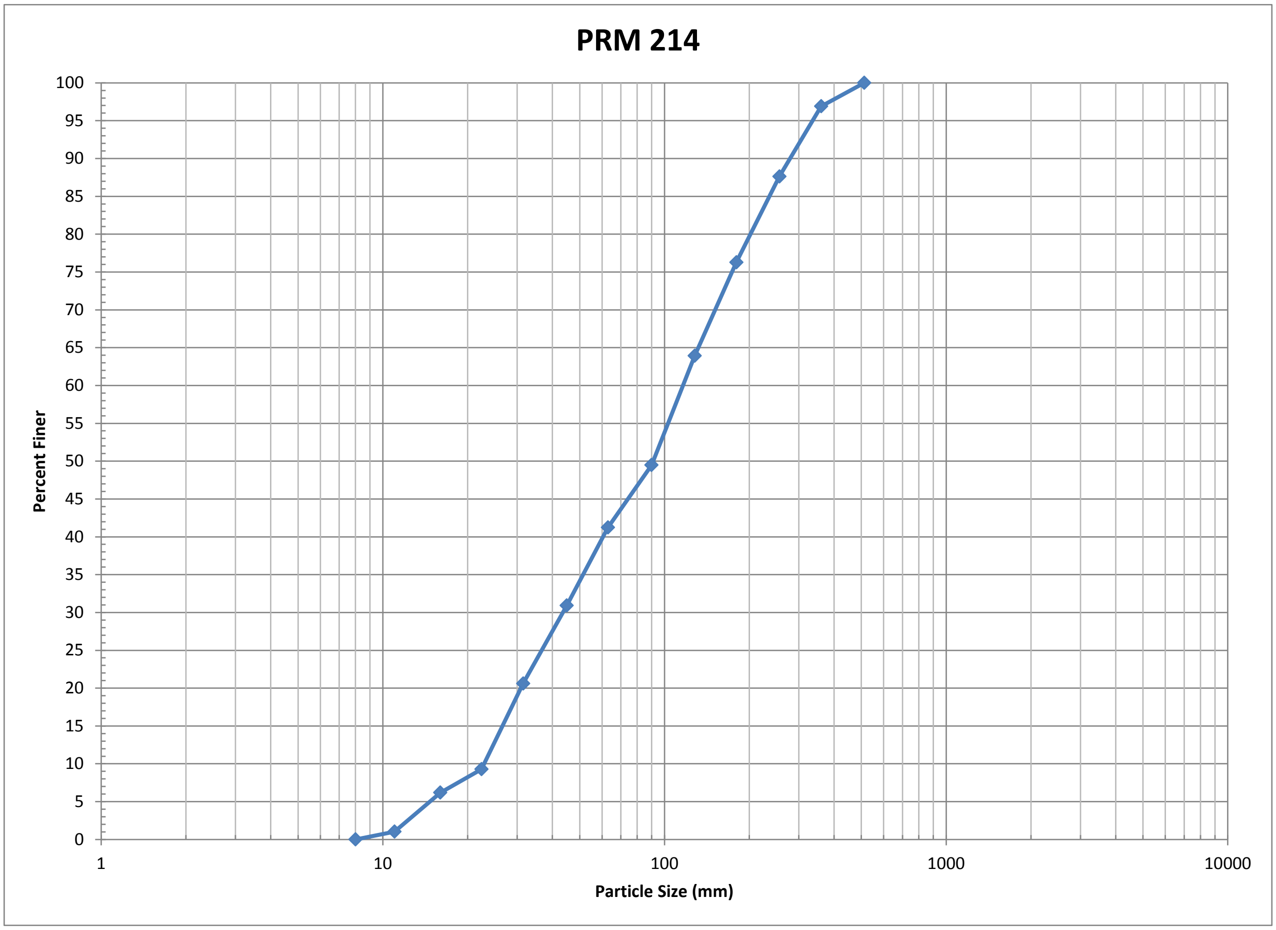

Figure A-4. Gradation curve for sample transect Susitna PRM 214.0.

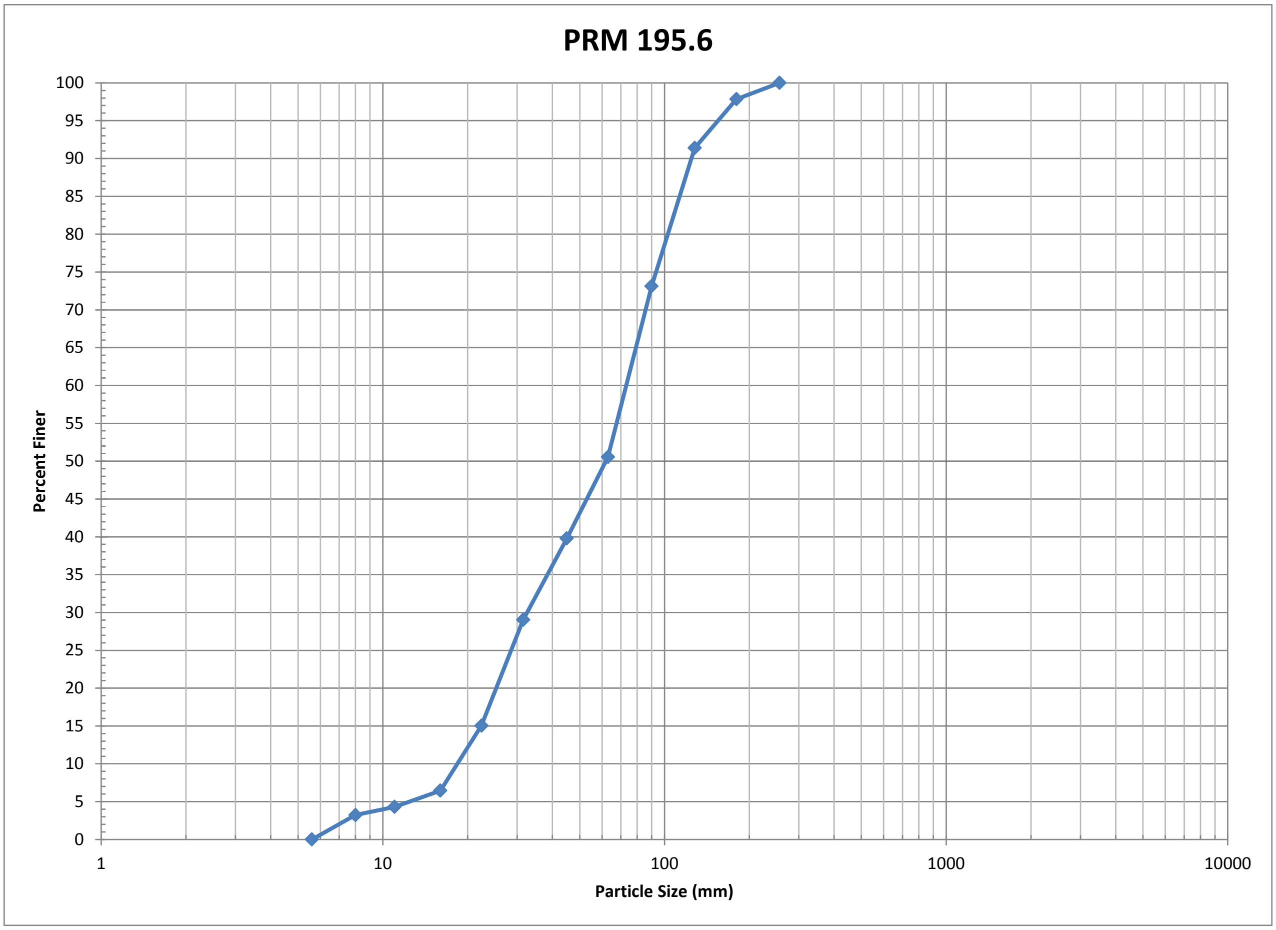

Figure A-5. Gradation curve for sample transect Susitna PRM 195.6.

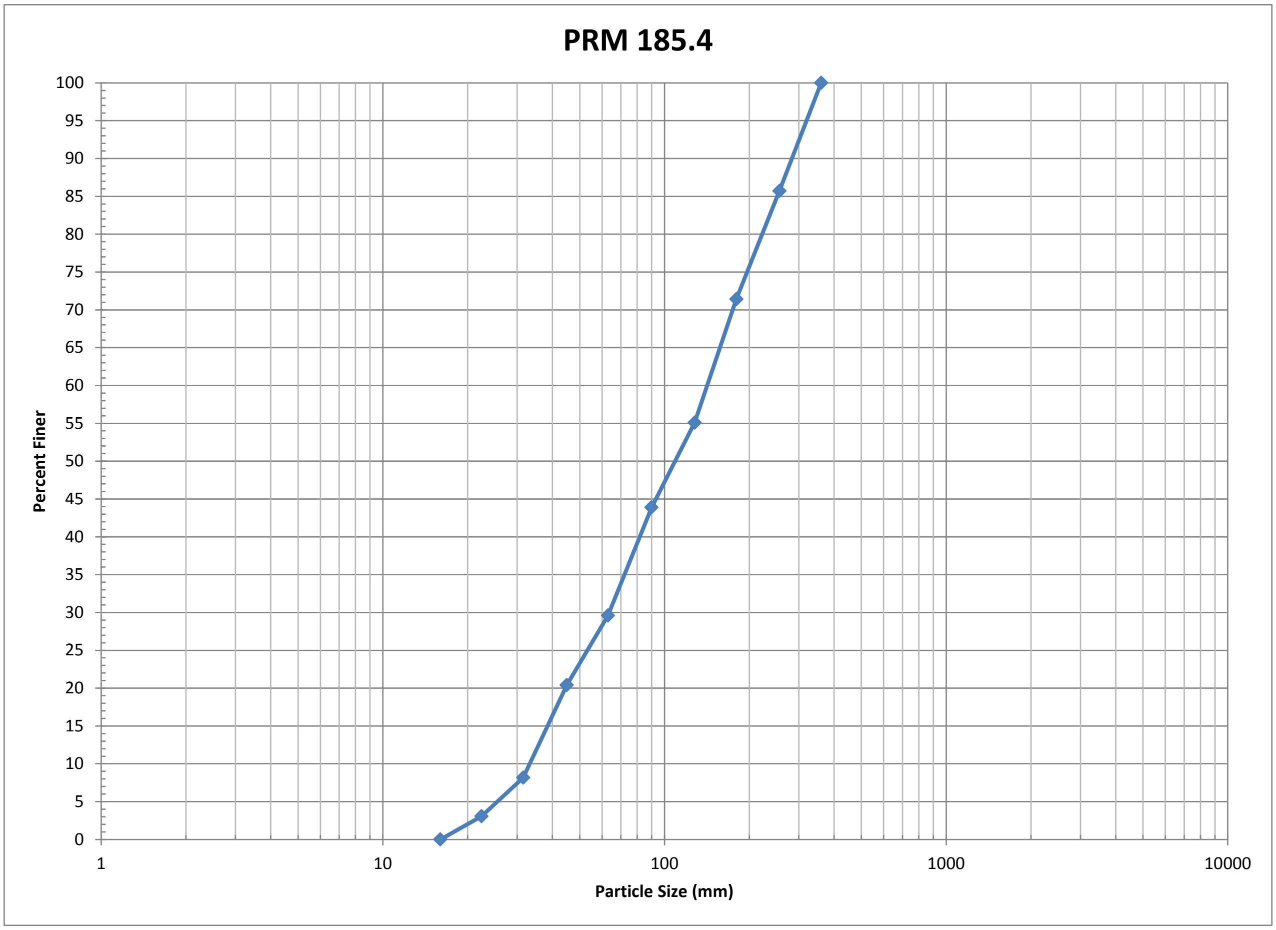

Figure A-6. Gradation curve for sample transect Susitna PRM 185.4.

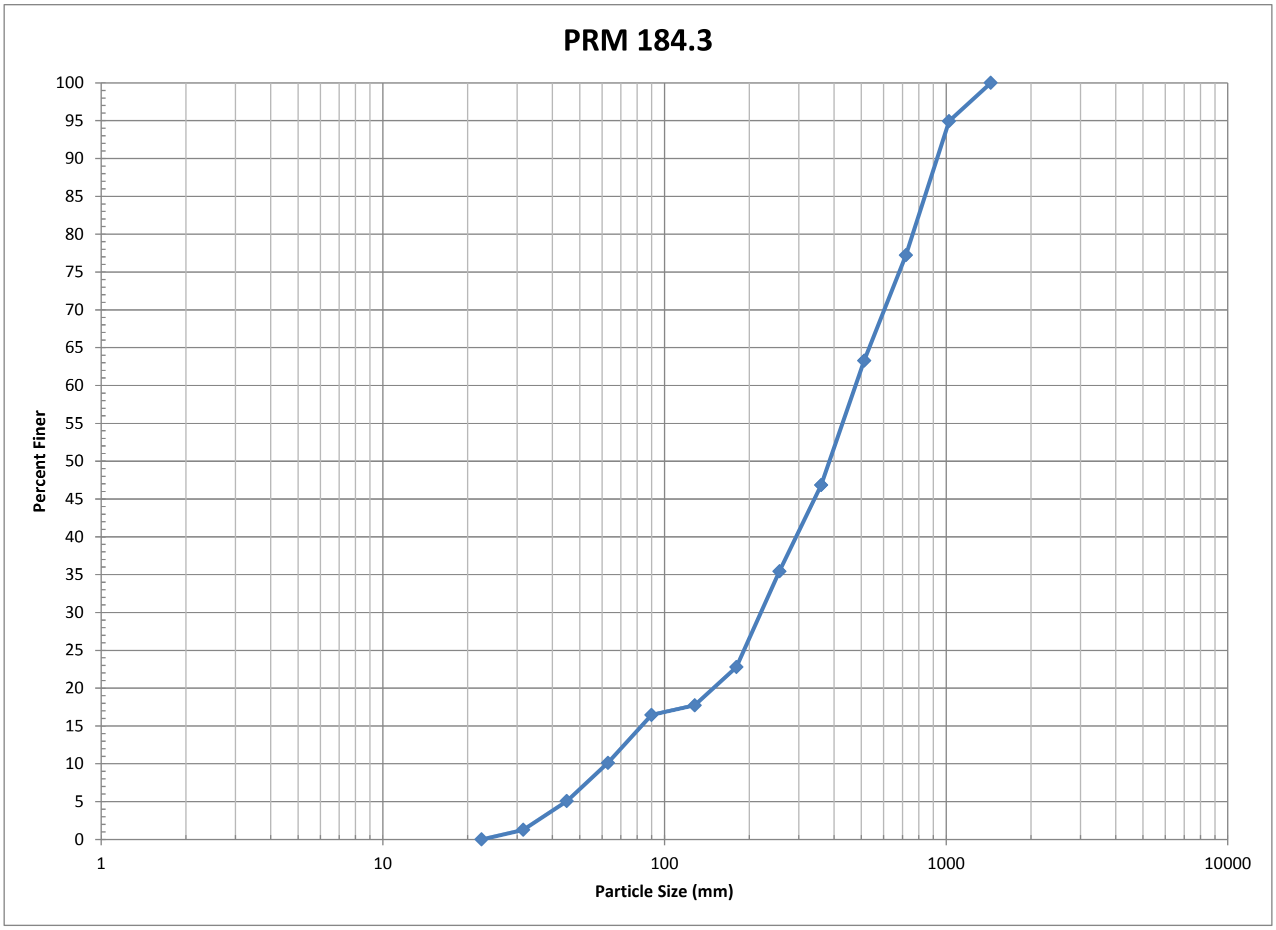

Figure A-7. Gradation curve for sample transect Susitna PRM 184.3.

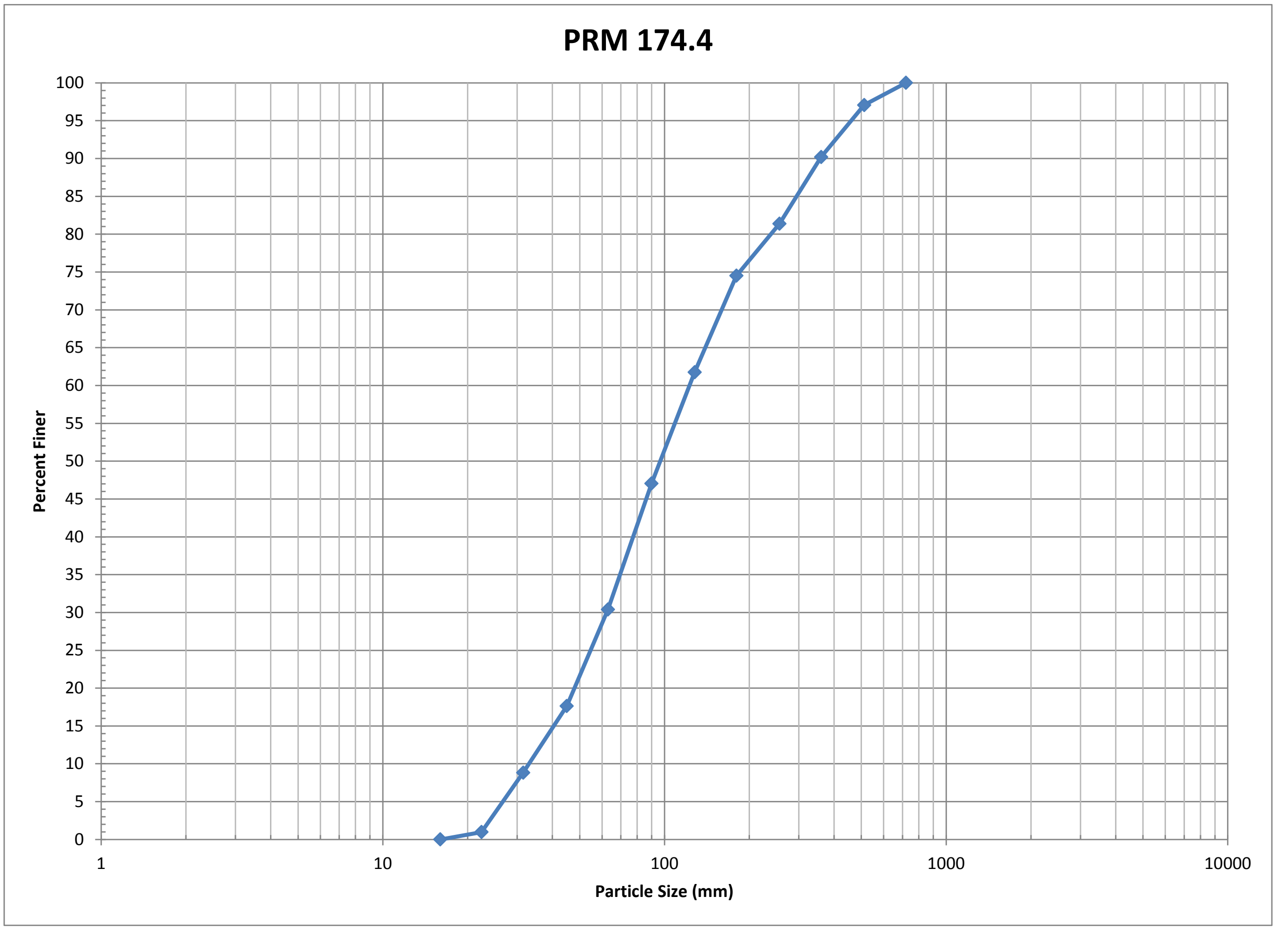

Figure A-8. Gradation curve for sample transect Susitna PRM 174.4.

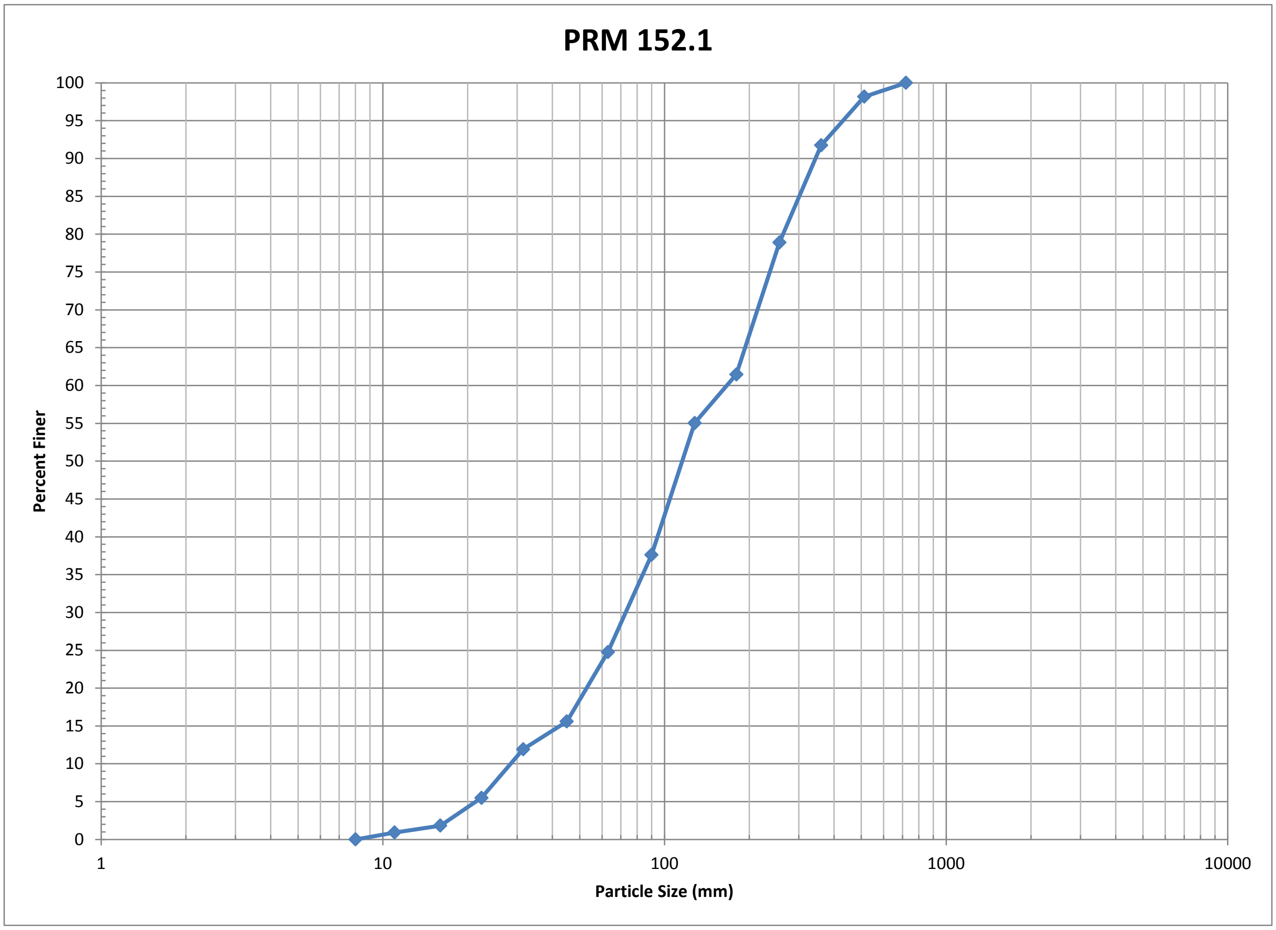

Figure A-9. Gradation curve for sample transect Susitna PRM 152.1.

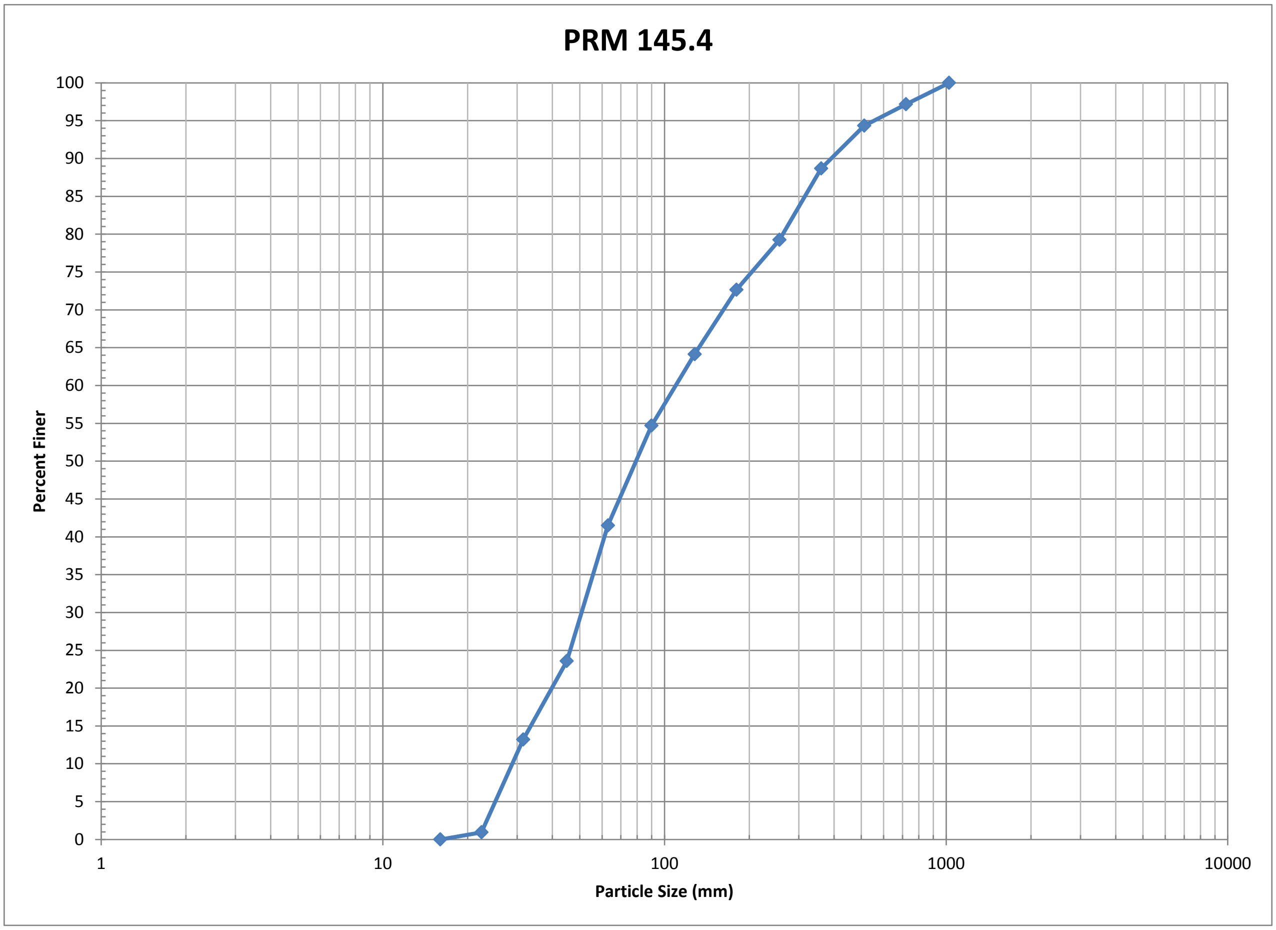

Figure A-10. Gradation curve for sample transect Susitna PRM 145.4.

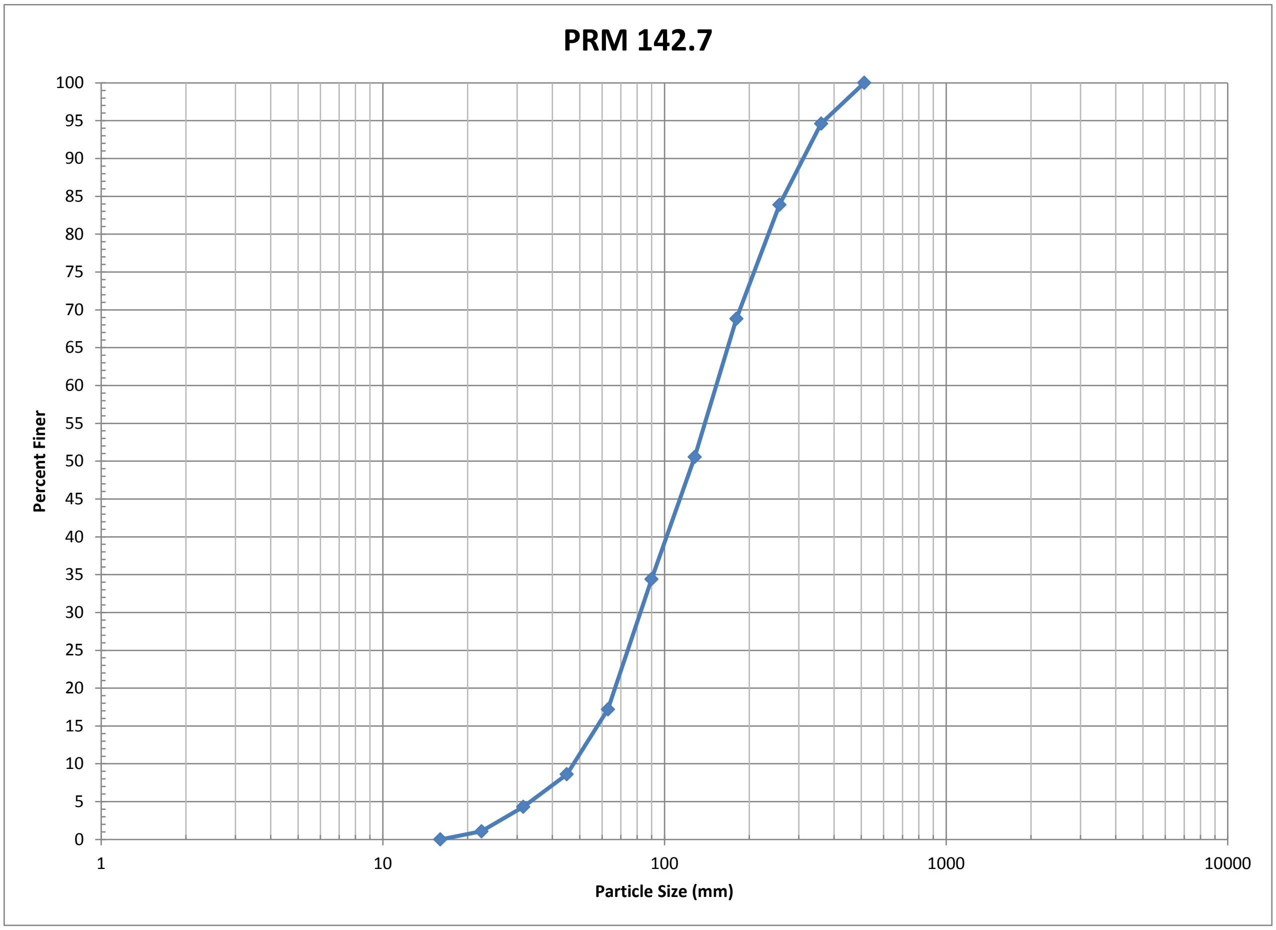

Figure A-11. Gradation curve for sample transect Susitna PRM 142.7.

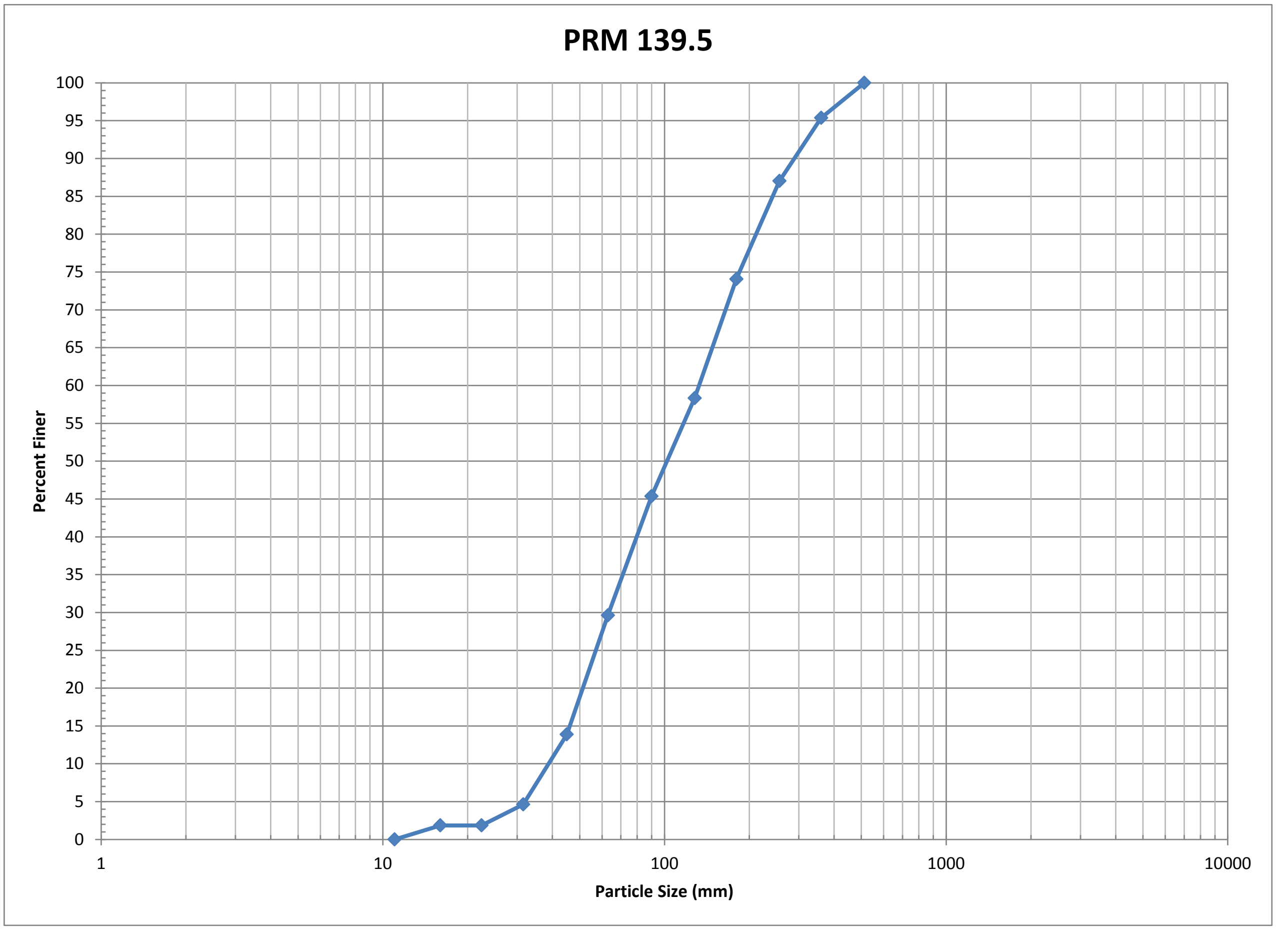

Figure A-12. Gradation curve for sample transect Susitna PRM 139.5.

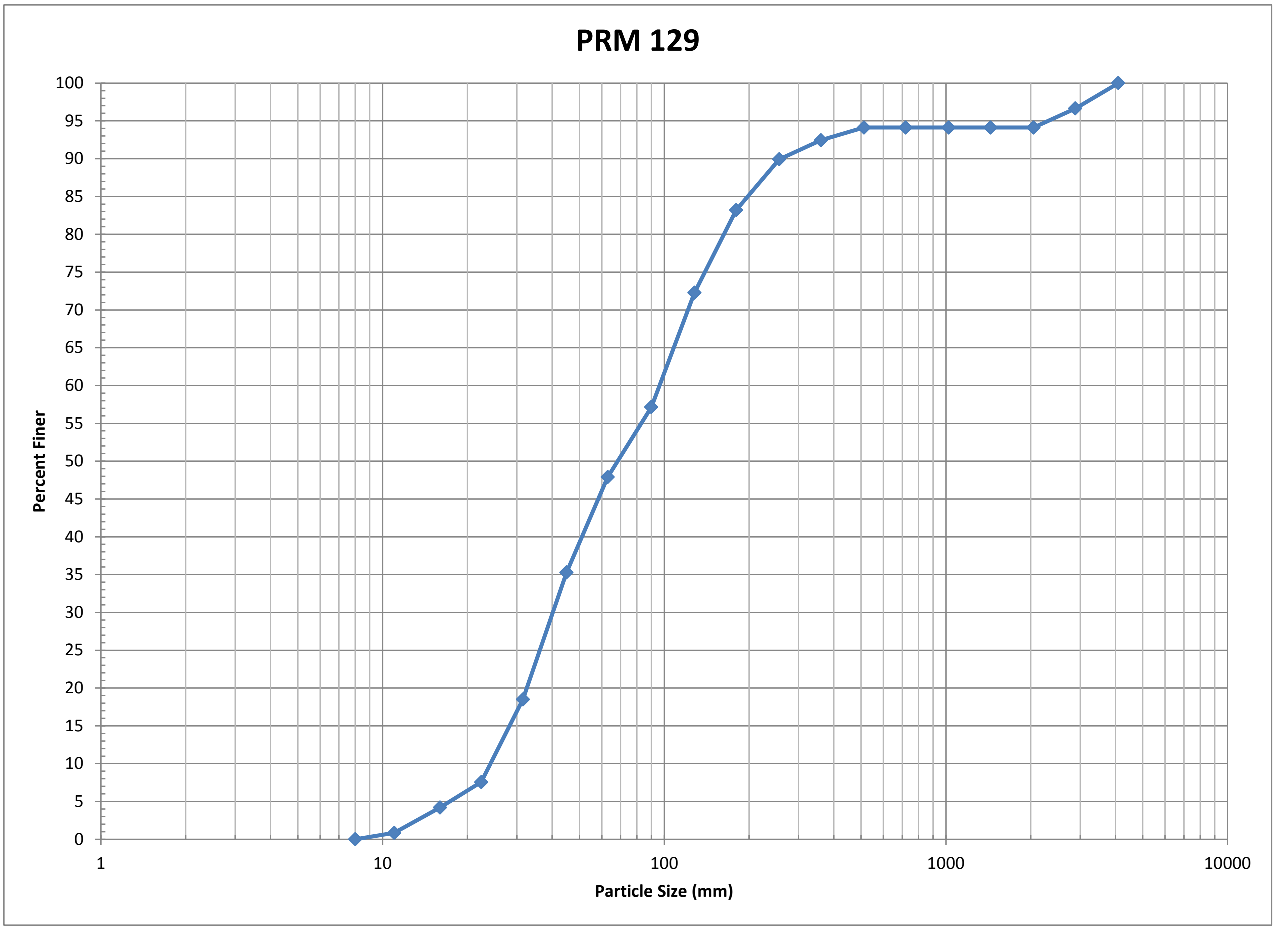

Figure A-13. Gradation curve for sample transect Susitna PRM 129.0.

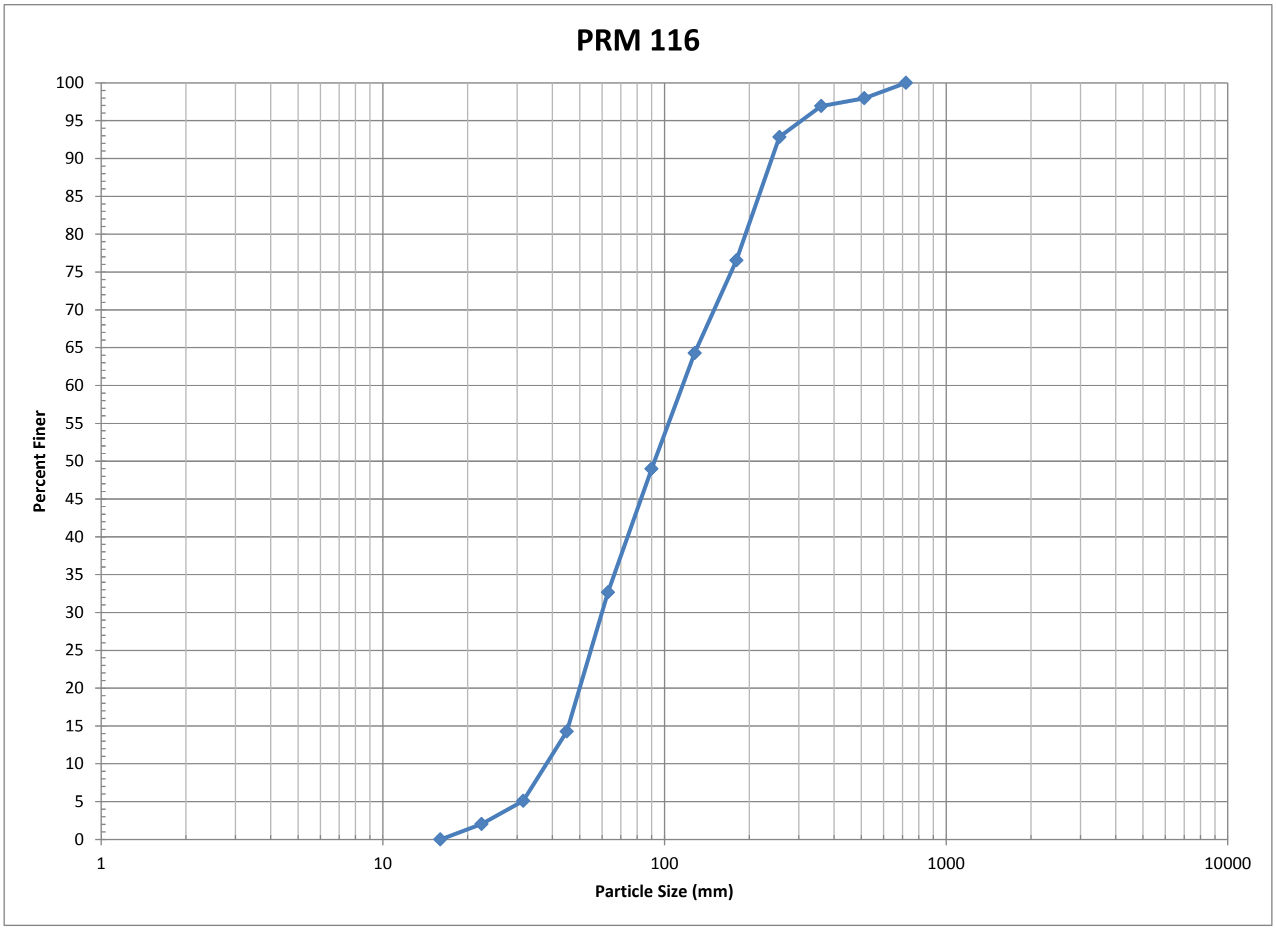

Figure A-14. Gradation curve for sample transect Susitna PRM 116.0.

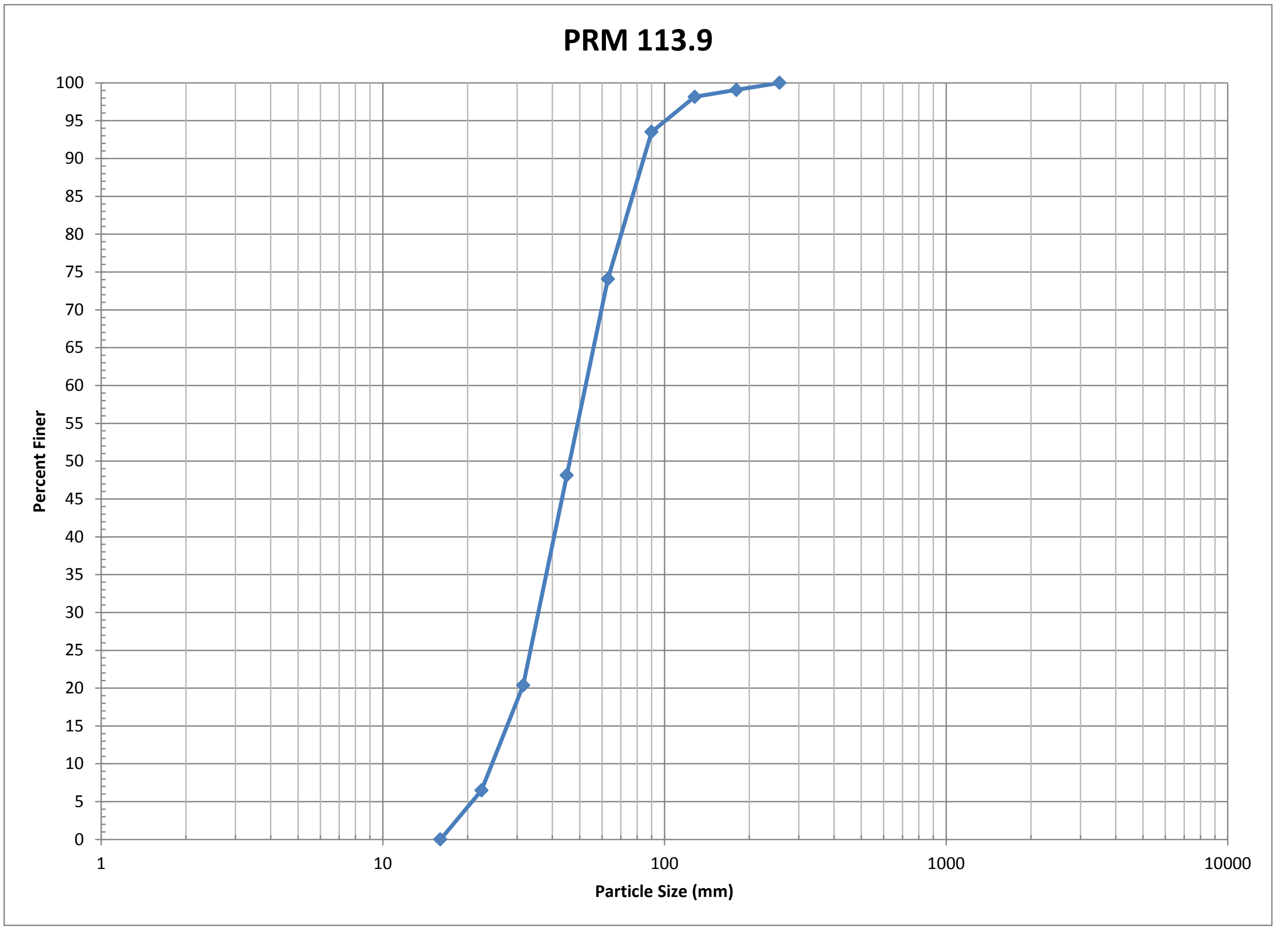

Figure A-15. Gradation curve for sample transect Susitna PRM 113.9.

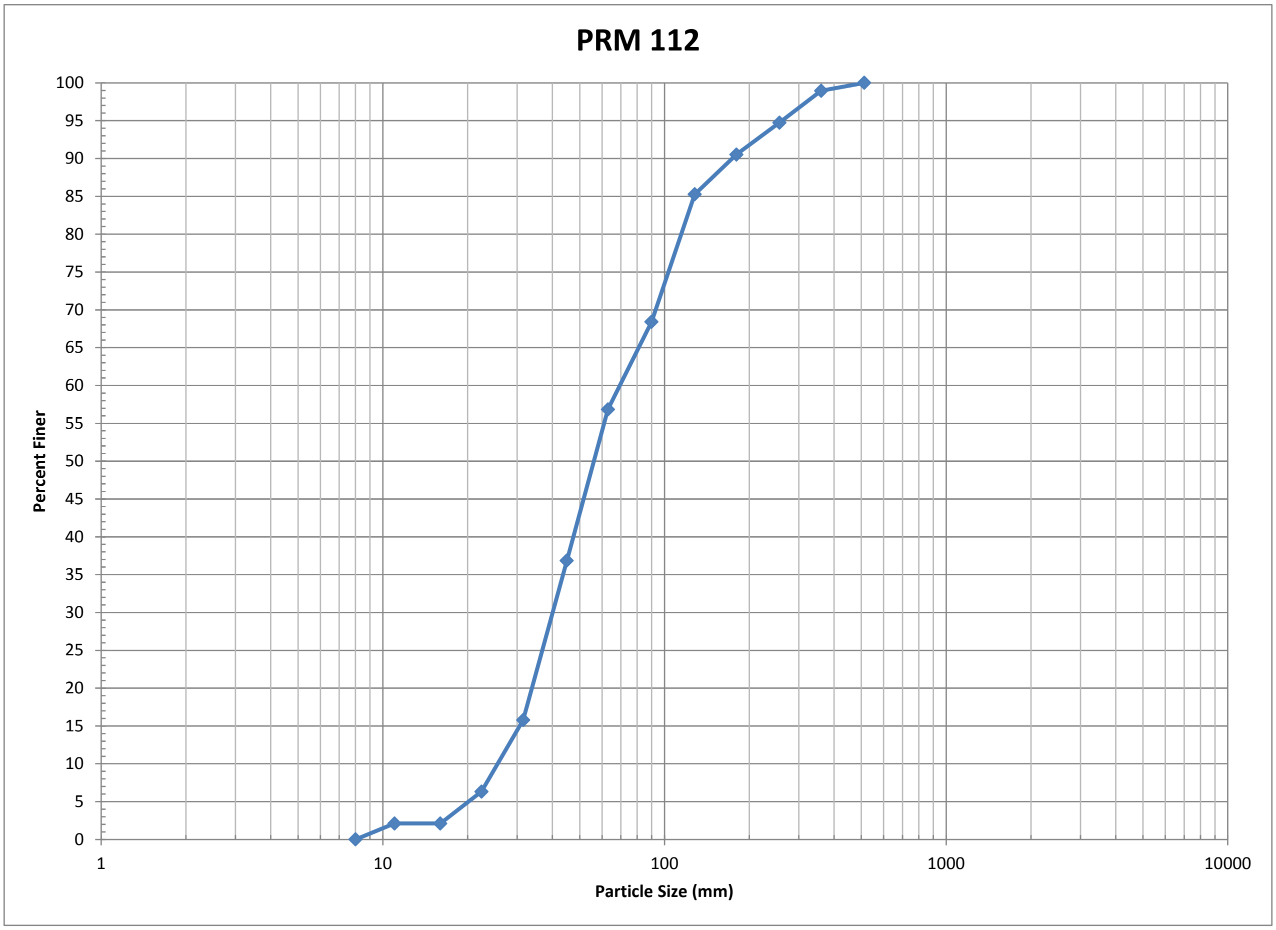

Figure A-16. Gradation curve for sample transect Susitna PRM 112.0.

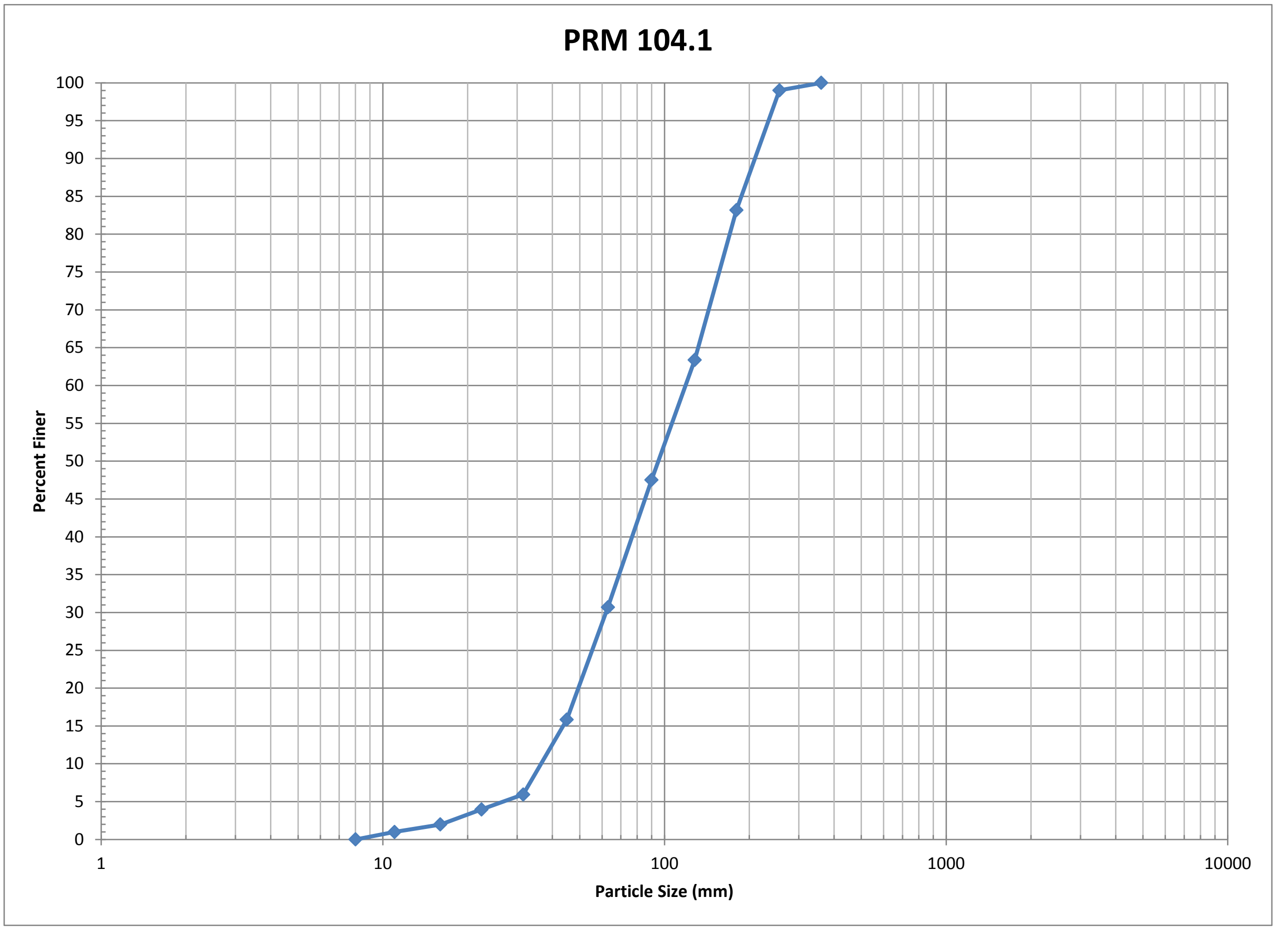

Figure A-17. Gradation curve for sample transect Susitna PRM 104.1.

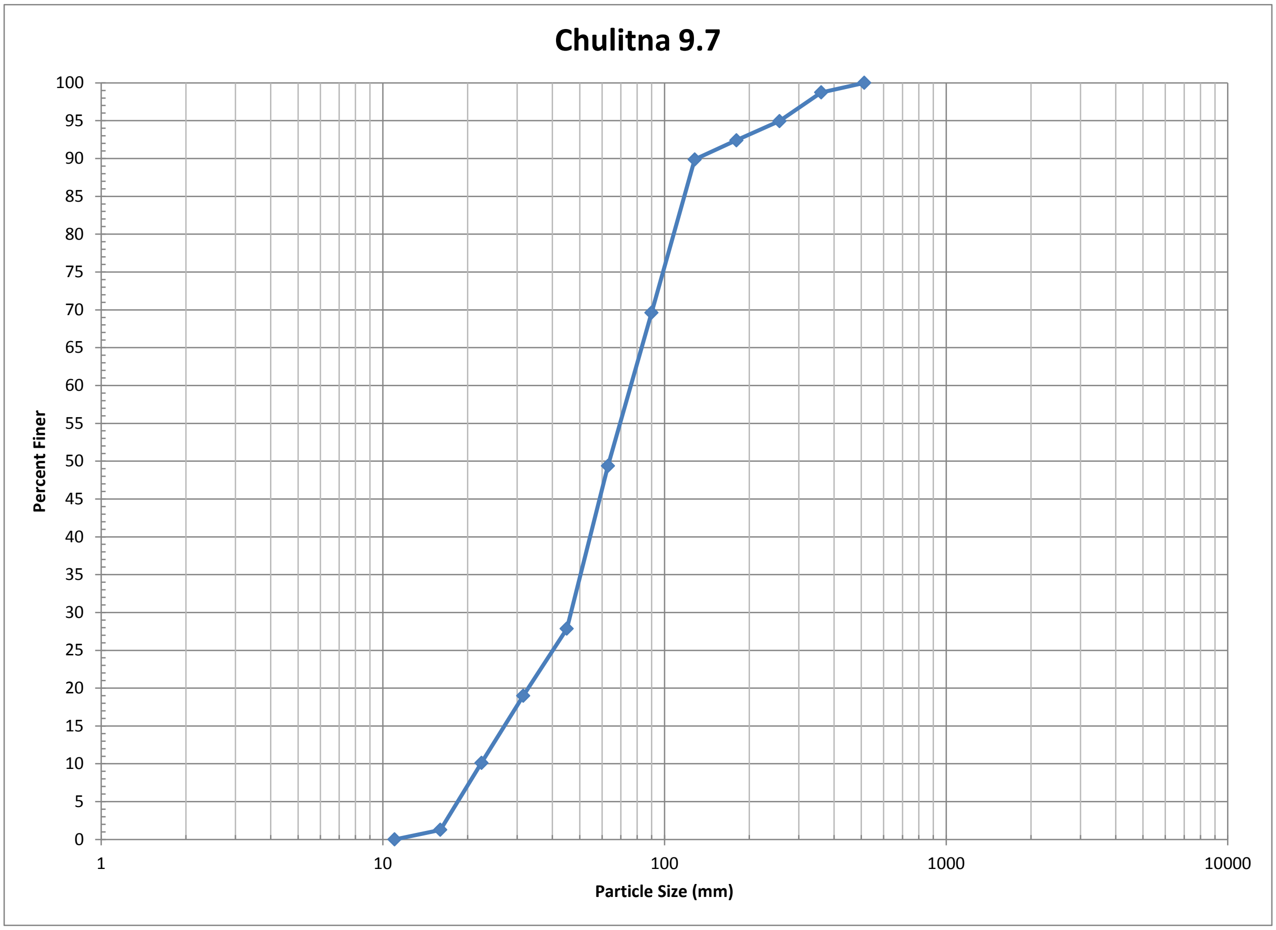

Figure A-18. Gradation curve for sample transect Chulitna PRM 9.7.

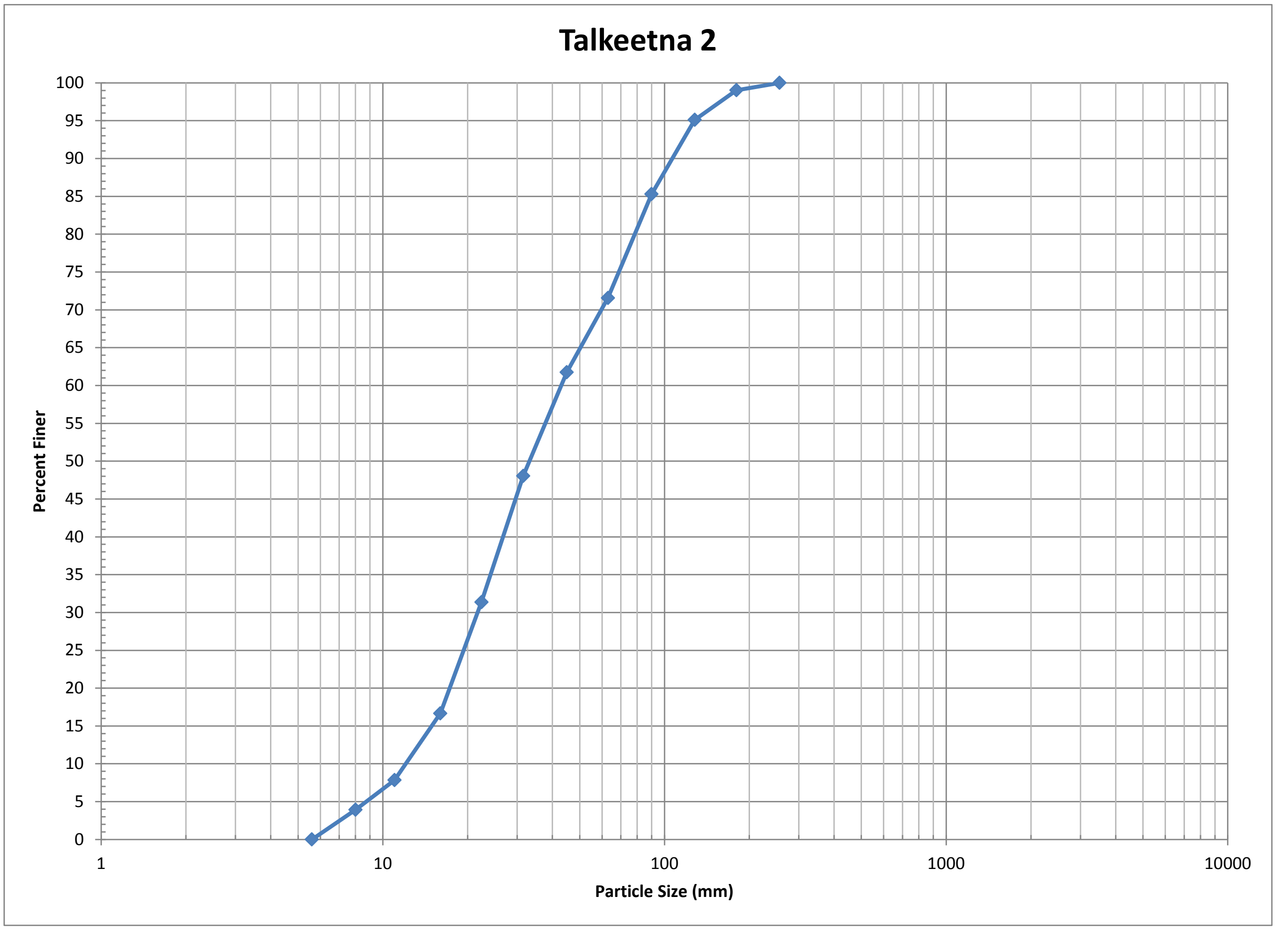

Figure A-19. Gradation curve for sample transect Talkeetna PRM 2.0.

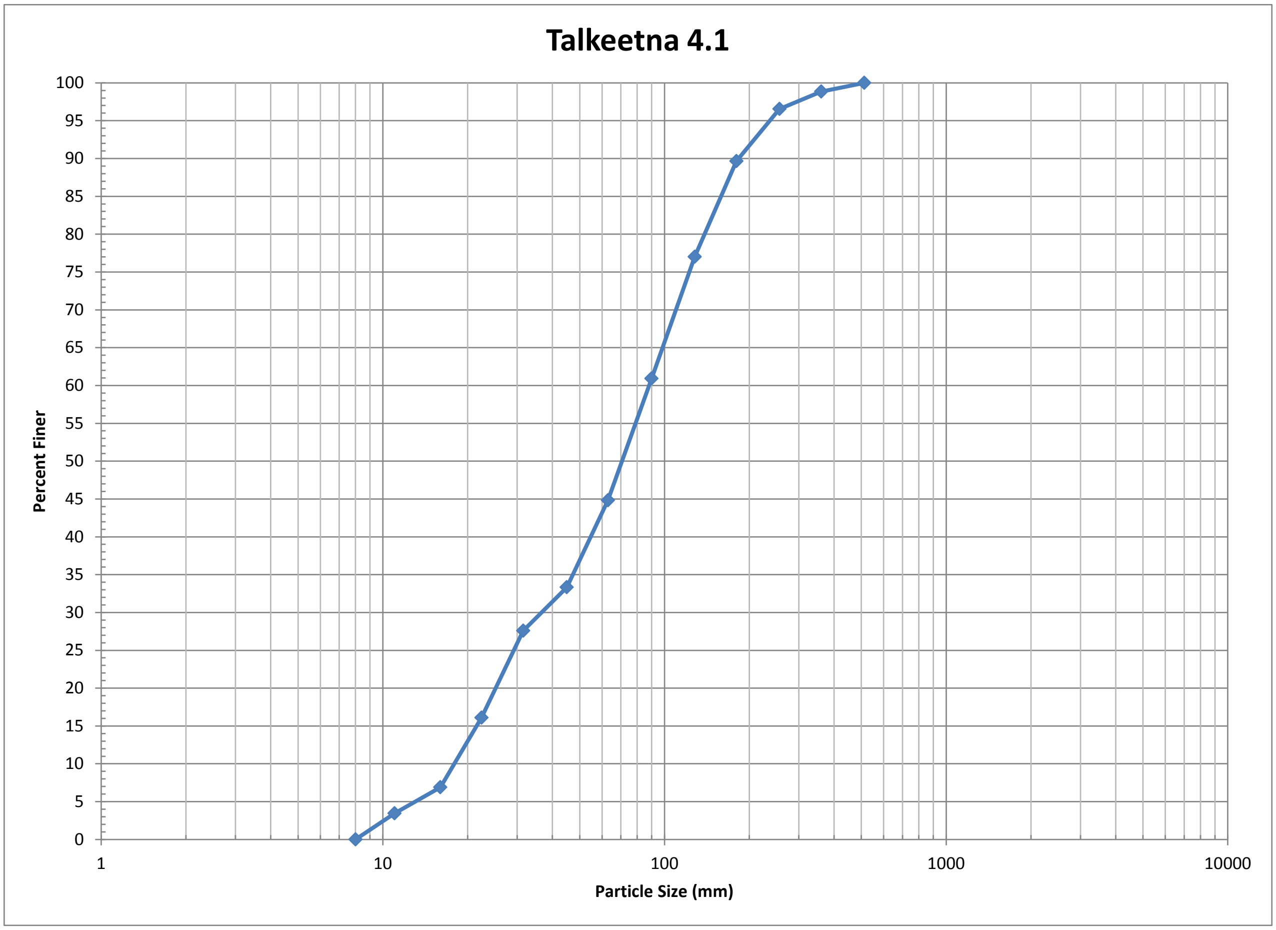

Figure A-20. Gradation curve for sample transect Talkeetna PRM 4.1.

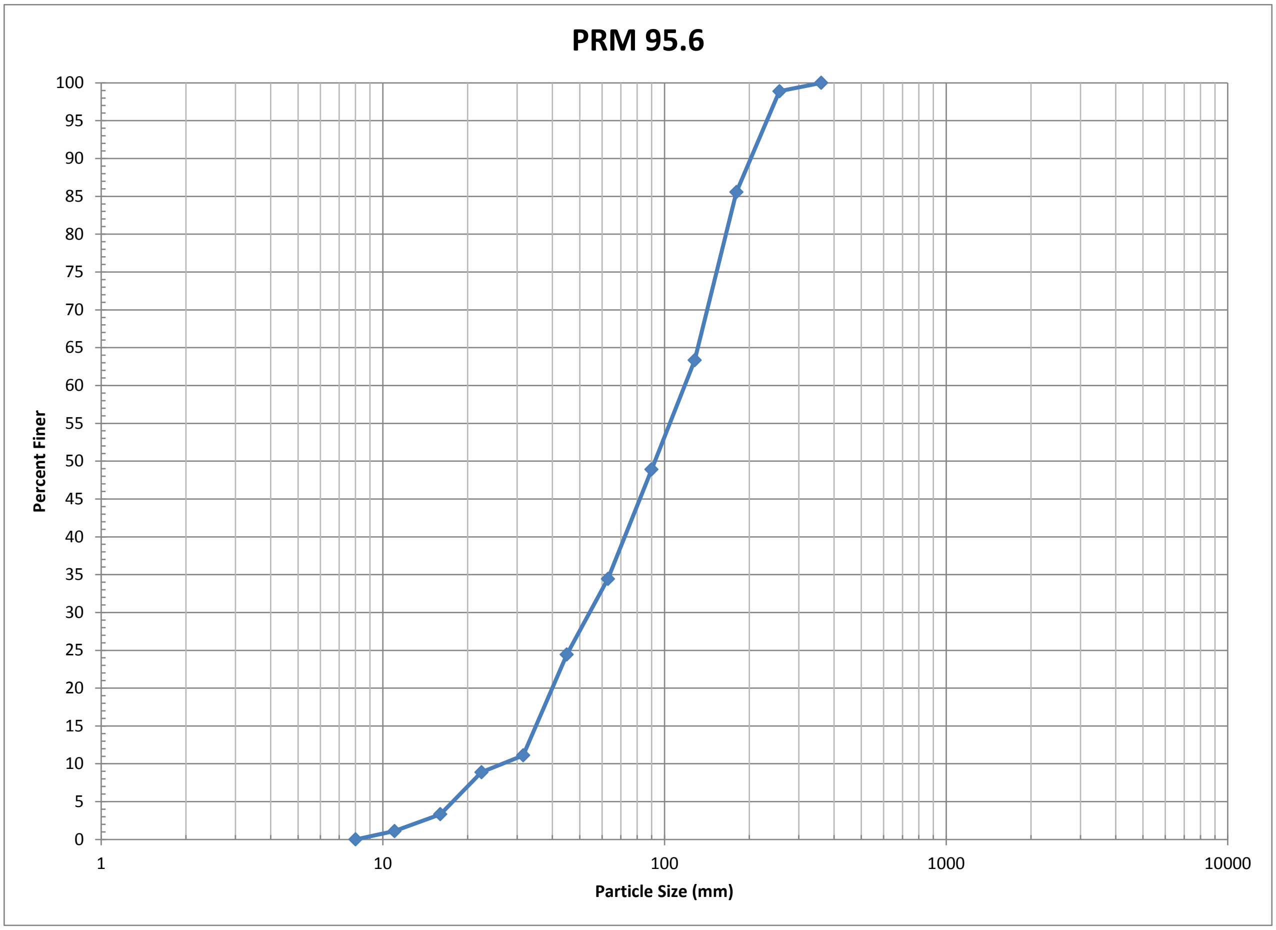

Figure A-21. Gradation curve for sample transect Susitna PRM 95.6.

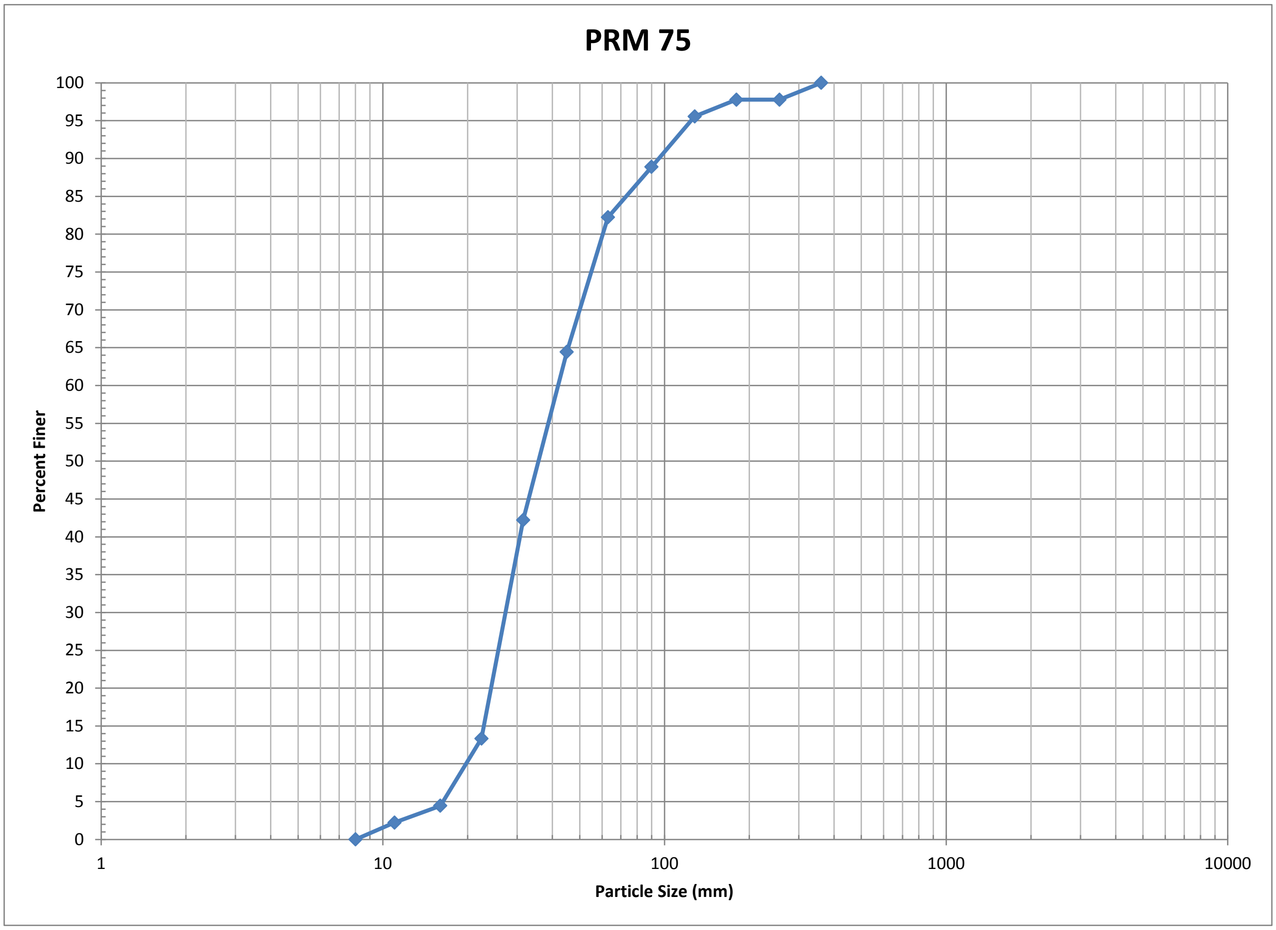

Figure A-22. Gradation curve for sample transect Susitna PRM 75.0.

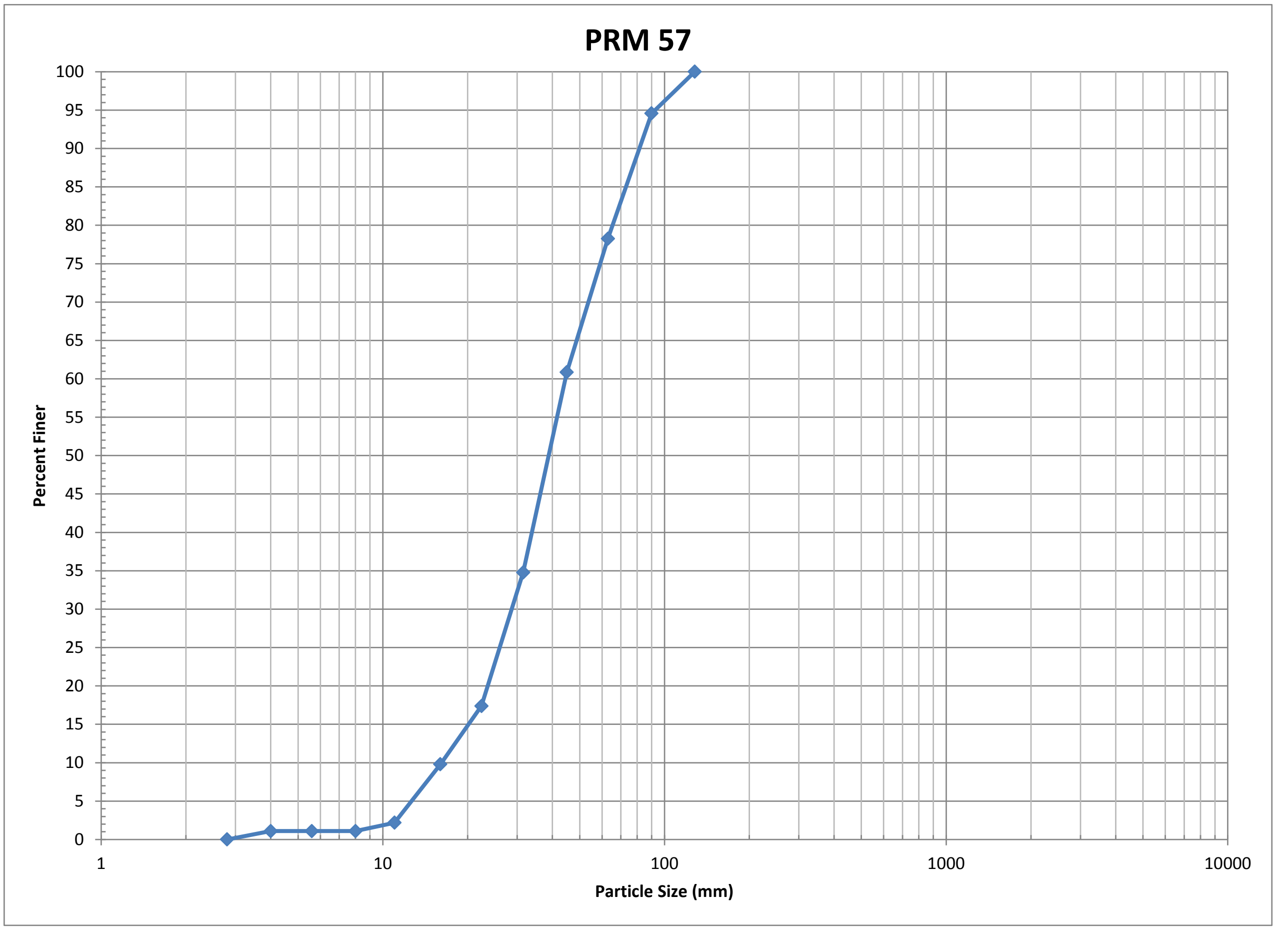

Figure A-23. Gradation curve for sample transect Susitna PRM 57.0.

APPENDIX B. MAIN CHANNEL TRANSECT GRADATION TABULATION

Table B-1. Tabulation of the gradations as percent finer than the equivalent sieve sizes and statistical grain size descriptor values for the Upper River winter bed material samples.

	Percent finer																												
	Equivalent Sieve Size (mm)																								Size Descriptors				
PRM	2	2.8	4	5.6	8	11	16	22.4	31.5	45	63	90	128	180	256	360	512	720	1024	1440	2048	2880	4096		D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)	Gr
195.6	0	0	0	0	3.2	4.3	6.5	15.1	29	39.8	50.5	73.1	91.4	97.8	100	100	100	100	100	100	100	100	100		22.9	62	111	125	2.2
214	0	0	0	0	0	1	6.2	9.3	20.6	30.9	41.2	49.5	63.9	76.3	87.6	96.9	100	100	100	100	100	100	100		27.4	91.1	229	280	2.9
230.1	0	0	0	0	0	0	2.9	6.9	9.8	11.8	16.7	30.4	38.2	52	63.7	82.4	87.3	91.2	96.1	99	99	100	100		60	171	404	648	2.6
240	0	0	0	0	0	0	0	6.4	9	16.7	16.7	28.2	38.5	55.1	65.4	87.2	97.4	100	100	100	100	100	100		43.6	162	342	397	2.9
253.6	0	0	2.5	4.9	9.9	9.9	12.3	13.6	22.2	29.6	35.8	42	56.8	69.1	74.1	90.1	100	100	100	100	100	100	100		24.6	109	316	359	3.7

Table B-2. Tabulation of the gradations as percent finer than the equivalent sieve sizes and statistical grain size descriptor values for the Middle River winter bed material samples.

	Percent finer																											
	Equivalent Sieve Size (mm)																							Size Descriptors				
PRM	2	2.8	4	5.6	8	11	16	22.4	31.5	45	63	90	128	180	256	360	512	720	1024	1440	2048	2880	4096	D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)	Gr
104.1	0	0	0	0	0	1	2	4	5.9	15.8	30.7	47.5	63.4	83.2	99	100	100	100	100	100	100	100	100	45.2	95.1	183	209	2
112	0	0	0	0	0	2.1	2.1	6.3	15.8	36.8	56.8	68.4	85.3	90.5	94.7	98.9	100	100	100	100	100	100	100	31.6	56.2	125	174	2
113.9	0	0	0	0	0	0	0	6.5	20.4	48.1	74.1	93.5	98.1	99.1	100	100	100	100	100	100	100	100	100	28.3	46.1	75.6	84.4	1.6
116	0	0	0	0	0	0	0	2	5.1	14.3	32.7	49	64.3	76.5	92.9	96.9	98	100	100	100	100	100	100	46.4	92.1	211	241	2.1
129	0	0	0	0	0	0.8	4.2	7.6	18.5	35.3	47.9	57.1	72.3	83.2	89.9	92.4	94.1	94.1	94.1	94.1	94.1	96.6	100	29.1	68.3	188	260	2.5
139.5	0	0	0	0	0	0	1.9	1.9	4.6	13.9	29.6	45.4	58.3	74.1	87	95.4	100	100	100	100	100	100	100	47.1	102	236	289	2.2
142.7	0	0	0	0	0	0	0	1.1	4.3	8.6	17.2	34.4	50.5	68.8	83.9	94.6	100	100	100	100	100	100	100	60.1	127	257	311	2.1
145.4	0	0	0	0	0	0	0	0.9	13.2	23.6	41.5	54.7	64.2	72.6	79.2	88.7	94.3	97.2	100	100	100	100	100	34.7	79.3	304	391	3.1
152.1	0	0	0	0	0	0.9	1.8	5.5	11.9	15.6	24.8	37.6	55	61.5	78.9	91.7	98.2	100	100	100	100	100	100	45.7	116	293	344	2.5
174.4	0	0	0	0	0	0	0	1	8.8	17.6	30.4	47.1	61.8	74.5	81.4	90.2	97.1	100	100	100	100	100	100	42.2	96.5	283	357	2.6
184.3	0	0	0	0	0	0	0	0	1.3	5.1	10.1	16.5	17.7	22.8	35.4	46.8	63.3	77.2	94.9	100	100	100	100	87.5	385	824	929	3.3
185.4	0	0	0	0	0	0	0	3.1	8.2	20.4	29.6	43.9	55.1	71.4	85.7	100	100	100	100	100	100	100	100	39.6	109	246	284	2.5

Table B-3. Tabulation of the gradations as percent finer than the equivalent sieve sizes and statistical grain size descriptor values for the Chulitna River and Talkeetna River winter bed material samples.

		Percent finer																												
		Equivalent Sieve Size (mm)																								Size Descriptors				
River	PRM	2	2.8	4	5.6	8	11	16	22.4	31.5	45	63	90	128	180	256	360	512	720	1024	1440	2048	2880	4096		D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)	Gr
Chulitna	9.7	0	0	0	0	0	0	1.3	10.1	19	27.8	49.4	69.6	89.9	92.4	94.9	98.7	100	100	100	100	100	100	100		28.1	63.7	116	130	2
Talkeetna	2	0	0	0	0	3.9	7.8	16.7	31.4	48	61.8	71.6	85.3	95.1	99	100	100	100	100	100	100	100	100	100		15.5	33.2	87	107	2.4
Talkeetna	4.1	0	0	0	0	0	3.4	6.9	16.1	27.6	33.3	44.8	60.9	77	89.7	96.6	98.9	100	100	100	100	100	100	100		22.3	70.7	154	183	2.7

Table B-4. Tabulation of the gradations as percent finer than the equivalent sieve sizes and statistical grain size descriptor values for the Lower River winter bed material samples.

	Percent finer																												
	Equivalent Sieve Size (mm)																								Size Descriptors				
PRM	2	2.8	4	5.6	8	11	16	22.4	31.5	45	63	90	128	180	256	360	512	720	1024	1440	2048	2880	4096		D16 (mm)	D50 (mm)	D84 (mm)	D90 (mm)	Gr
57	0	0	1.1	1.1	1.1	2.2	9.8	17.4	34.8	60.9	78.3	94.6	100	100	100	100	100	100	100	100	100	100	100		21.1	38.8	71.4	81.4	1.8
75	0	0	0	0	0	2.2	4.4	13.3	42.2	64.4	82.2	88.9	95.6	97.8	97.8	100	100	100	100	100	100	100	100		23.1	35.7	69.3	95.4	1.7
95.6	0	0	0	0	0	1.1	3.3	8.9	11.1	24.4	34.4	48.9	63.3	85.6	98.9	100	100	100	100	100	100	100	100		35.9	92.5	176	202	2.2