Piney Run Watershed Study
Piney Run Dam

Maryland Dam No. 139 (NID ID: MD00139)

Sediment Evaluation

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1. Introduction

The purpose of this report is to provide the research necessary to estimate the rate of sediment delivery, identify possible sources of sediment, and estimate a projected sediment life of the Piney Run reservoir structure. The report investigates future sediment rates and available volume based on historical sedimentation, and future productions based on watershed changes over the remaining existing service and rehabilitation service lives (100 years). This report provides supporting data and information for inclusion in the Watershed Plan and Environmental Assessment document for Piney Run Reservoir.

1.1 Site Overview

The following are the overall site parameters:

- Reservoir Normal Pool Elevation (EL.) – 524.0 feet*
- Reservoir Surface Area at Normal Pool Elevation – 290 acres
- Reservoir Normal Pool Depth (Deepest Location) – 54 feet (at lake drain)
- Two Largest Contributing Drainage Areas: Tributary 1 - 6.08 mi^2 and Tributary 2 - 1.59 mi^2
- Existing Stream Classification: Tributary 1 (Piney Run) - Rosgen C4 and Tributary 2 (Unnamed Tributary of Piney Run) – Rosgen E4 Stream Types
- Nearest USGS Stream Gage: 01586210 Beaver Run, Finksburg, MD
- Nearest USGS Stream Gage Drainage Area: 14 mi^2

For comparison to previous surveys and studies, elevations in this report are reported in the project datum reported on the as-built plans.

2. Methods

2.1 Introduction

A single frequency sonar is used to determine the existing bathymetry of the Piney Run reservoir. Sediment depths at various locations around the reservoir are measured manually using a sediment probe which pushed by hand into the sediment to refusal. The probe measurements were used to estimate sediment depths in the reservoir and to determine the total sediment volume in the reservoir. An existing geomorphology data analysis along with sediment transport model FLOWSED are used as the basis for predicting sediment volume delivered to the reservoir on an annualized basis from the upstream reaches of the Piney Run Reservoir.

2.2 Bathymetry Survey and Sediment Volume Calculations

To determine the volume of sediment and water in the reservoir during normal pool conditions, a bathymetric survey including sediment probing was completed. The data was collected, post-processed, and analyzed to determine an estimate of the sediment and water depths at various locations in the reservoir and to estimate the volume of sediment in the reservoir. The bathymetric survey was performed by using a single-frequency sonar sensor mounted to a boat. The boat completed transects of the reservoir to collect depth data from the normal pool surface to the top of the sediment layer. Sediment probing was then completed in the reservoir to measure the depth of sediment at various locations, particularly at major inflow points to the reservoir where sediment accumulation is typically most prevalent.

The data was post-processed in ARCGIS v10.6 to create an existing conditions bathymetric model of the reservoir bottom as well as to estimate sediment volume. Bathymetry survey points were interpolated to create a raster dataset using the inverse distance weighting technique. The results of this analysis provide information to the total volume of sediment in the reservoir and the total volume of water in the reservoir at normal pool.

2.3 Sediment Competence Calculations

Sediment competence calculations are appropriate for gravel, cobble, and boulder-bed stream systems. The general premise of sediment competence evaluation is to compare existing channel hydraulics to the hydraulic conditions required to mobilize the largest anticipated particle size during bankfull flow. With this information a general determination of channel stability can be made.

The results of the competence calculations provide information on predicting if erosional rates are expected to increase or decrease over the remaining life of the reservoir due to existing and future watershed changes.

2.4 Sediment Capacity and FLOWSED and POWERSED Models

Evaluation of sediment capacity was completed using FLOWSED. This will determine how quickly sediment accumulates within the Piney Run reservoir to approximate the remaining storage life left on the reservoir.

FLOWSED model are used in concert for predicting annual sediment yield in riverine systems and evaluating changes in sediment capacity for a particular segment of the system. FLOWSED computes a total annual sediment yield based on a flow duration curve, which is a distribution of flows over a typical water year based on data from a local or nearby USGS stream gage, and a sediment rating curve, which is a relationship between flow and transport of bedload and suspended sediment transport rate.

The output results of the FLOWSED model include:

- Flow Duration Curve – which provides valuable information on the percentage of time certain flow levels exist within a stream. This is generated from a nearby USGS stream gage of a similar drainage area and then the gage data input into the model is made dimensionless by bankfull discharge and then scaled up or down to the supply reach by bankfull discharge; likewise, the mean daily equivalent for the bankfull discharge is also generated by the model.
- Sediment Rating Curves (SRCs)—using the bankfull bedload and suspended sediment transport rates, the dimensionless rating curve input above is made dimensional, resulting in a relationship between discharge and transport rate for bedload, total suspended sediment and total suspended less wash load.
- FLOWSED—total annual sediment yield based solely on the flow duration curve and sediment rating curves.

3. Site Analysis

3.1 Bathymetric and Sediment Volume Analysis

AECOM completed the bathymetric survey using methods described in section 2. The reservoir currently holds a total volume of water of approximately 5,311 acre-feet (1.73 billion gallons) at a normal pool EL. 524.0 feet. AECOM reviewed previous bathymetric surveys performed on the reservoir. Two previous efforts were identified: a 1988 survey by Greenhorne and O'Mara and a 2013 survey by the Maryland Department of the Environment (MDE). The 1988 survey indicated that the reservoir volume at the normal pool elevation was approximately the same as the design volume (reported as 6,041 acre-feet). The 2013 survey indicated a normal pool volume of 5,528 acre-feet or a loss of 508 acre-feet from the original design volume. It should be noted that the survey map provided as part of the MDE survey indicated that the survey did not cover the upper end of the reservoir or the upstream end of several inlet areas of the reservoir which were covered in the other surveys. AECOM's 2019 survey reflects a 725 acre-feet storage loss from original design with those losses occurring between 1988 and 2019 as indicated by the total storage volume from the 1988 survey. The storage loss since 2013 is 217 acre-feet although the difference may be able to be explained, in part, by the absence of survey information in the 2013 survey that would have covered the areas of the reservoir most prone to sedimentation. See Figure 1 below.

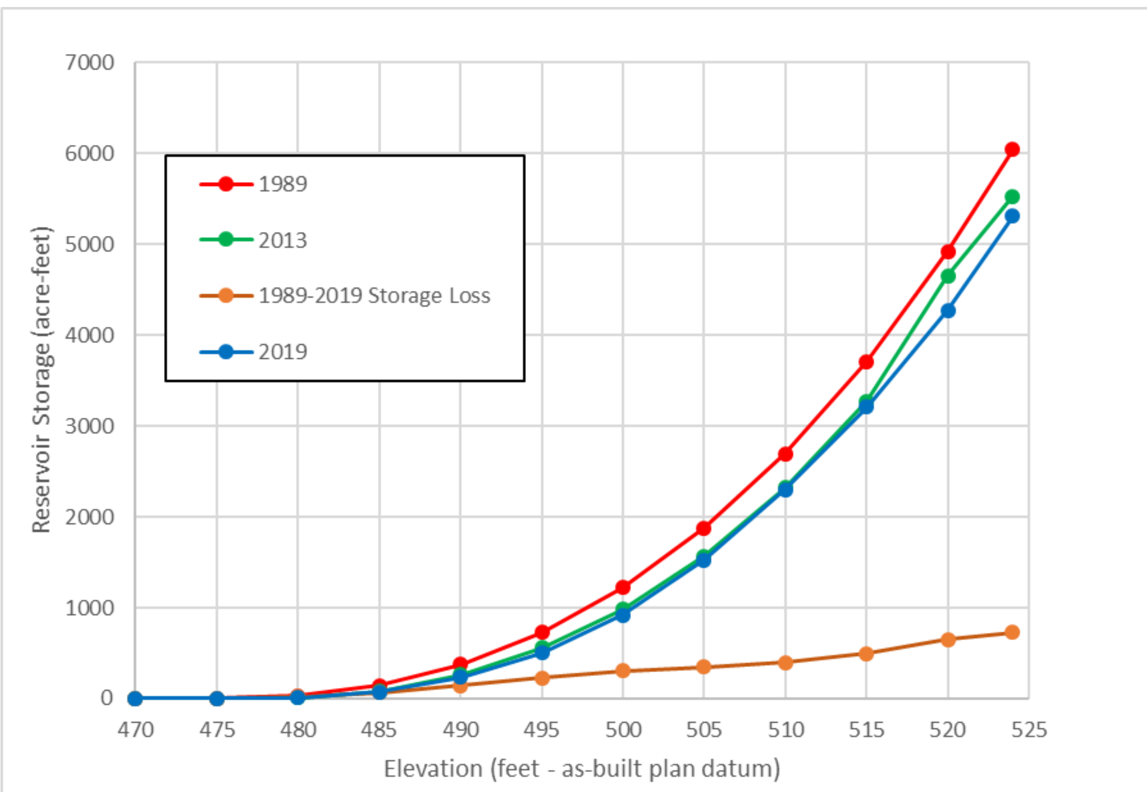


Figure 1. Comparison of elevation-storage ratings from historical bathymetric surveys.

Therefore, the estimated accumulated sediment in the reservoir is 725 acre-feet. If averaged over the 45-year lifespan of the reservoir (1974 to 2019), the annualized sediment accumulation is approximately 16 acre-feet. However, given that the 1988 survey reported minimal sedimentation, the rate may be closer to approximately 23 acre-feet per year.

The sediment probe samples showed thicker sediment layers in the upstream ends of the reservoir's coves, particularly those at the upstream end of the reservoir with the sediment accumulation dissipating rapidly moving downstream in the coves toward the main portion of the reservoir. A review of photos taken prior to the first filling in 1974, the 1988 and 2013 surveys, and the results of this bathymetric survey show that the original stream channel which was incised by approximately four to six feet prior to first filling has been generally filled in.

A map of the existing conditions bathymetry and sediment probe sample locations and depths is provided in Appendix A.

3.2 Stream Site Selection

AECOM reviewed the recent bathymetric and watershed characteristics of the Piney Run reservoir to identify the locations upstream of the dam that contribute the largest amount of discharge and potential annualized sediment contribution. See Figure 2 below for a site assessment location map.

The site identified as Tributary 1 is a stream reach of Piney Run located near Brass Eagle Drive and includes approximately 2,500 LF upstream from its confluence with the reservoir. This reach is a perennial stream that is medium to large in size (greater than 20 ft bankfull width). The watershed area at the outlet of Tributary 1 into Piney Run reservoir is approximately 3,901 acres. Land cover distribution for this watershed is 59% agricultural, 13% developed, and 28% forested based on data from the 2016 National Land Cover Dataset (NLCD).

Tributary 2 is a stream reach of an unnamed Tributary of Piney Run located near Colodon Farms Road and includes approximately 1,000 LF upstream from its confluence with the reservoir. This reach is a perennial stream that is small to medium in size (less than 20 ft bankfull width). The watershed area at the outlet of Tributary 2 into Piney Run reservoir is approximately 913 acres. Land cover distribution for this watershed is 54% agricultural, 23% developed, and 23% forested based on data from the 2016 NLCD.

Combined, Tributaries 1 and 2 represent approximately 4,815 acres or approximately 74% of the total non-reservoir watershed with land cover distributed as 58% agricultural, 14% developed, and 27% forested. This land cover distribution is similar to the overall total non-reservoir land cover distribution of 53% agricultural, 15% developed, and 32% forested. Because these two tributaries collect drainage from nearly three quarters of the overall watershed and because the land cover distribution is very similar to that of the overall watershed, they were considered representative of the entire watershed.

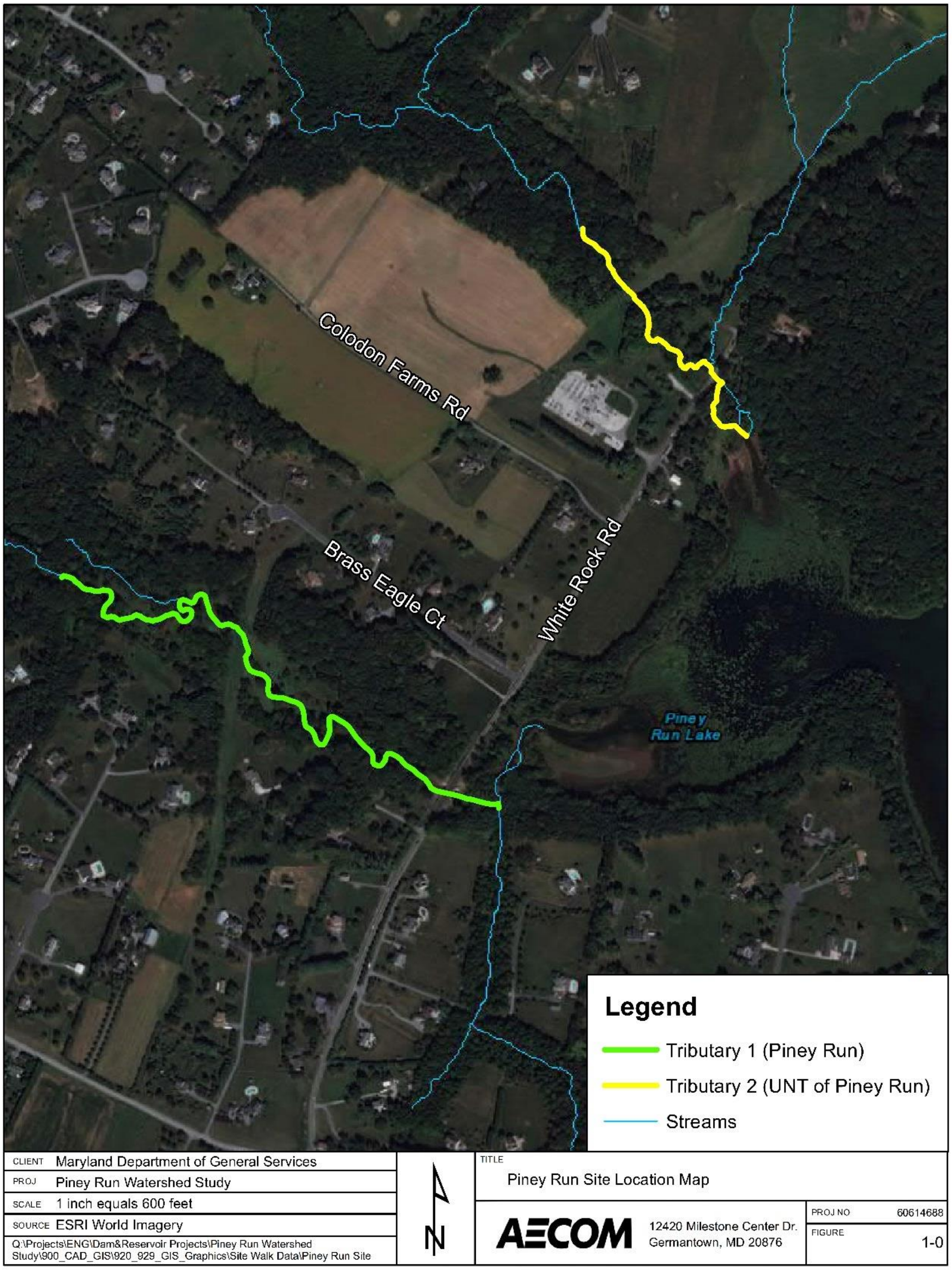


Figure 2. Site assessment location map.

3.3 Stream Geomorphic Assessment

3.3.1 Stream Assessment Methodology

In November 2019 AECOM visited the site of the Piney Run reservoir to collect fluvial geomorphic data on portions of the most significant contributing stream channels for both discharge and sediment. The data is used in evaluating the stability of the streams flowing into the reservoir and provides input into the calculations to estimate the potential sediment supply from those streams.

The geomorphic assessment was performed using the stream classification, assessment, and analysis techniques included in Levels I through III of the Rosgen methodology (Rosgen, 1996). In this methodology, streams are categorized based on their measured field values of width-to-depth ratio, entrenchment ratio, sinuosity, average water surface slope, and bed form materials, see Figure 3 below.

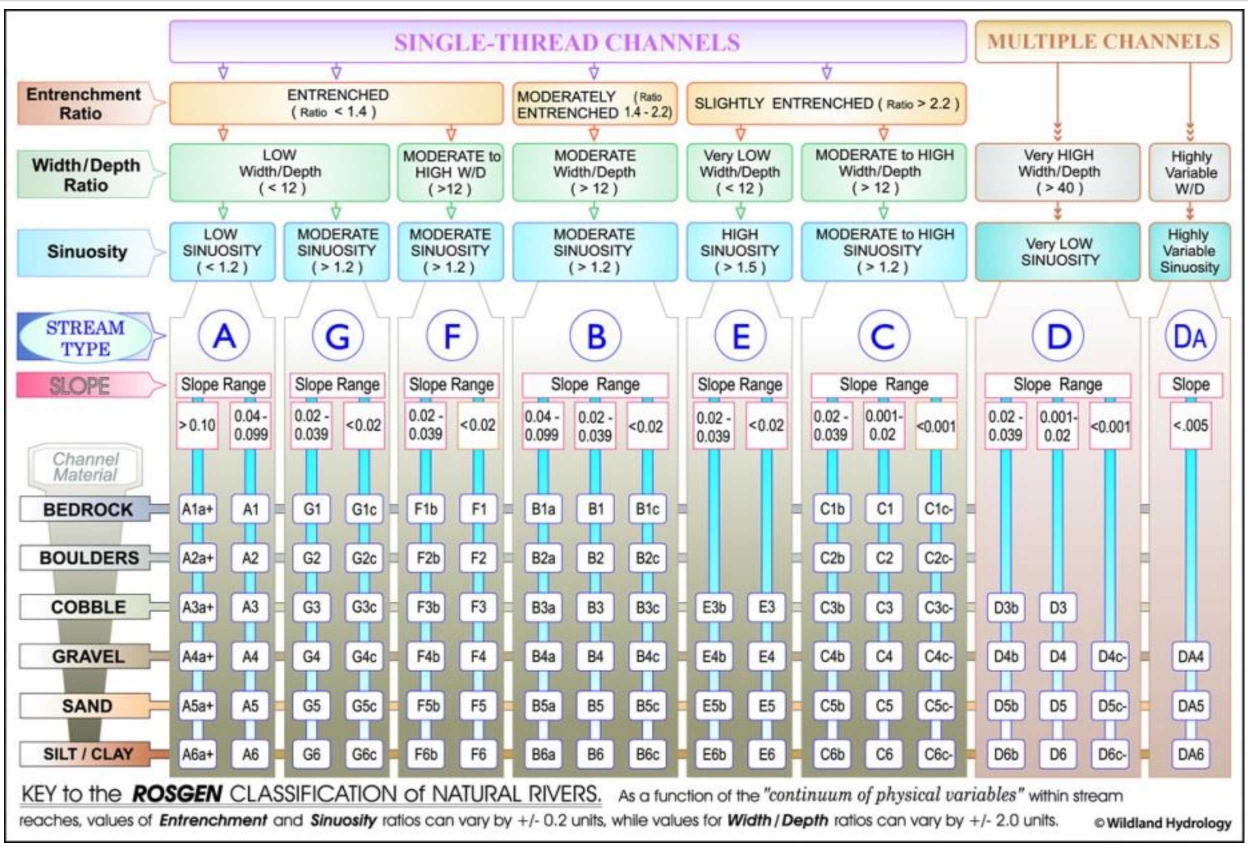


Figure 3. Key to Rosgen classification of natural rivers (Rosgen, 1996).

3.3.2 Initial Assessment

AECOM conducted an initial visual assessment of Tributary 1 and 2 stream reaches to evaluate existing conditions. Special attention was placed on identifying stream bank indicators of bankfull discharge and to look for representative riffle/pool habitat. This data was used to evaluate the existing stream stability and its degree of departure from reference conditions.

Initial investigation of Tributary 1 showed multiple signs of lateral and vertical instability such as raw and exposed vertical banks, fallen trees from root erosion, channel incision and floodplain disconnection, and transverse, mid channel and side bar formation. Evidence from the stream banks suggest the stream has been in a state of degradation for a number of years possibly as a byproduct of development of the immediate upstream area. Degradation is defined as the lowering of the local base level of the stream bed through the process of excess bed scour and channel incision over time. Current conditions show channel incision of one to two feet in elevation from the abandoned floodplain.

Initial investigation of Tributary 2 showed multiple signs of lateral and vertical instability raw and exposed vertical and undercut banks, channel incision and disconnection from the floodplain. Evidence from the stream banks suggest the stream has been in a state of degradation for a number of years, possibly as a byproduct of development of the immediate upstream area. Current conditions show channel incision for 0.5 to one foot in elevation from the abandoned floodplain.

Both tributaries had torturous meanders and multiple channel blockages have formed within the existing channels due to excess large woody debris from fallen trees and lateral and vertical instability. This has contributed to the formation of transverse and mid channel bars that increase near bank stress, which accelerates stream bank erosion rates. Furthermore, little to no existing stream bank protection is present because of the absence of deep rooting native vegetation and mature trees on the stream bank slopes in many areas.

Channel incision has caused a slight abandonment of the stream's connection to the floodplain. Consequently, high-discharge flow travels within the immediate channel boundary with little floodplain relief, casing high shear stresses which result in increased erosion rates.

3.3.3 Existing Stream Classification and Regional Curves

Tributary 1 and 2 geomorphic data was collected and analyzed using RIVERmorph 5.2.0 Professional software to determine geomorphic parameters, classification, vertical and lateral stability indices, bankfull discharge, and sediment competence. This data was then verified using regional curves specific to the Piedmont region of Maryland as noted in the "Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region, CBFO-S02-01, March 2002" report. This analysis required a stream gage dataset to use as in input. A search was conducted for acceptable stream gages within the Piedmont physiographic region and within a close proximity to the Piney Run Dam watershed. Two gauges, Piney Run gage (United States Geological Survey (USGS) Gage No. 01588000) located immediately downstream of the dam and Beaver Run (USGS Gage No. 01586210) located in Finksburg, Maryland, were considered since their watershed characteristics are similar to those of the Piney Run Dam watershed and both had reasonably long periods of record. The Beaver Run gage was selected since it is still an operable gage (Piney Run gage was discontinued after the dam was constructed in 1974). The data from this gage were referenced to help calibrate bankfull dimensions. The bankfull areas and discharges derived from this regional relationship for each reach are provided in Table 1, these parameters were used to verify field collected data at the project site. The actual existing geomorphic assessment data summary is shown in Table 2, and provided in Appendix C.

Table 1. Estimated Bankfull Summary from Regional Curves

Reach	Drainage Area (mi^2)	Bankfull Cross Sectional Area (ft^2)	Bankfull Velocity (fps)	Bankfull Discharge (cfs)
Tributary 1	6.08	65.05	5.12	333
Tributary 2	1.59	24.44	4.92	120

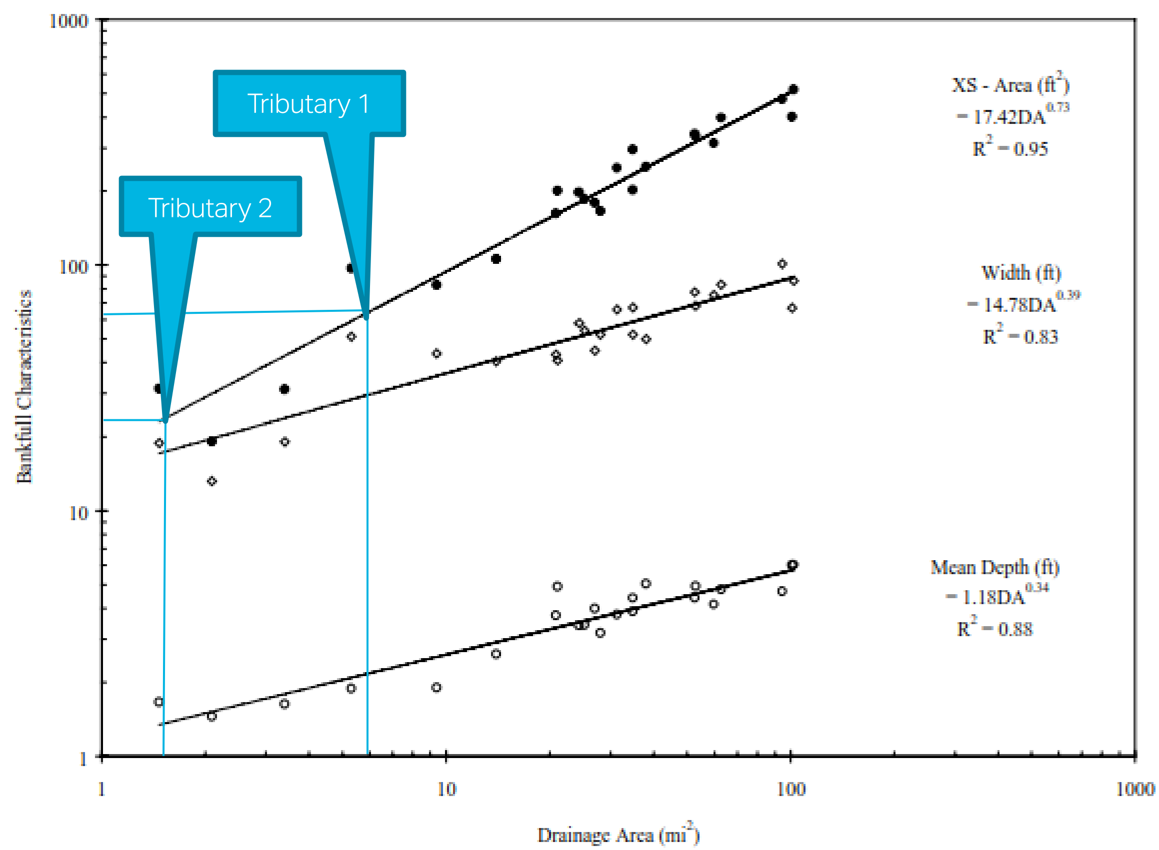
Table 2. Actual Existing Geomorphic Assessment Summary (November 2019)

	Bankfull Width	Mean Depth	Bankfull Area	W/D Ratio	Floodprone Width	Entrenchment Ratio	Water Surface Slope	Stream Type
Tributary 1	34.15	1.65	56.41	20.7	>100	>2.2	0.00308	C4/F4
Tributary 2	15.08	1.79	27.05	8.42	>50	>2.2	0.00509	F4

3.3.3.1 Tributary 1

The majority of the existing Tributary 1 reach is classified as a Rosgen C4 stream type. The lowest point of analysis at the end of the proposed LOD features a drainage area of approximately 6.08 square mile (3,891 acres). Tributary 1 is located in an unconfined alluvial valley (U-AL-FD). This type of alluvial valley is typically characterized as having a broad valley floor with terraces in association with floodplain, alluvial soils. The wide valley has a gentle, down-valley elevational relief (slopes less than 3.0%). The unconfined valley allows the stream lateral migration room to a degree that the associated valley width ratio is greater than 7.0 times the width of bankfull. Characteristics typical of a C4 stream types include gravel dominated, low gradient, meandering, point bar, riffle/pool alluvial channels with broad, well defined floodplains which characterize this type of channel as a stable stream type. However, many areas of Tributary 1 also showed signs of Rosgen F4 stream type. This type of channel is characterized by being gravel-dominated and having an entrenched, meandering riffle/pool channel on low gradients with a high width/depth ratio. Rosgen F4 stream types are unstable with lateral instability and high bank erosion rates.

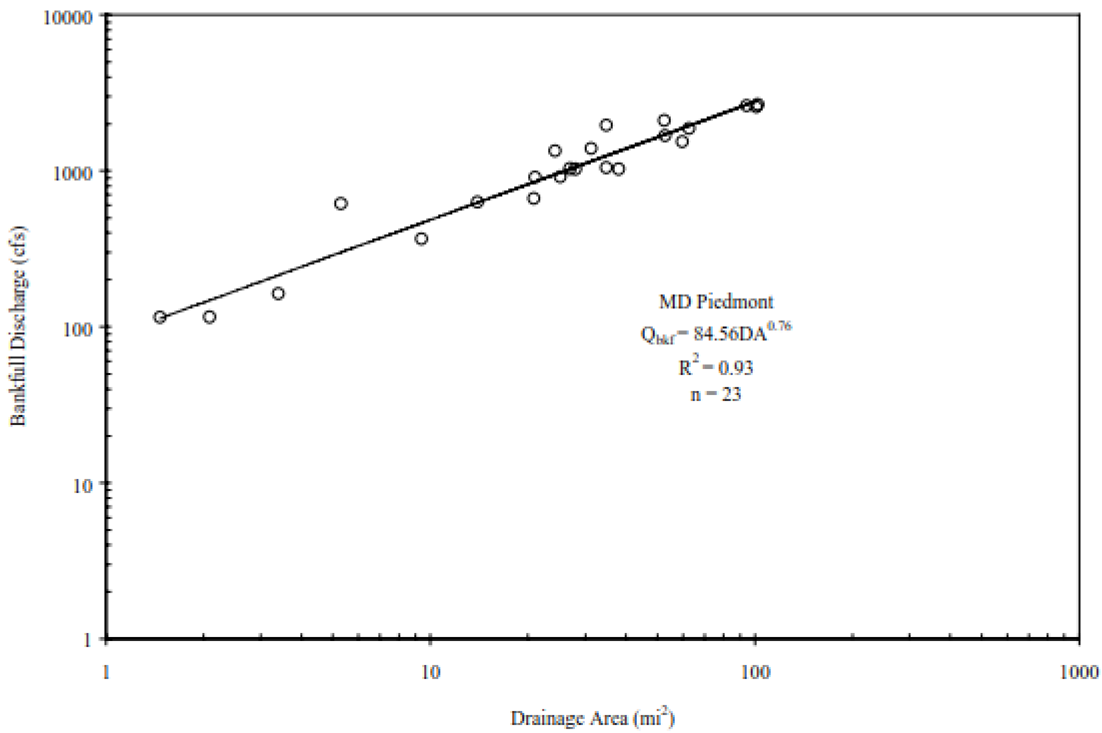
The bankfull area (Abkf) measured at the existing riffle was measured as 56.41 square feet (ft^2). This field calculation was compared to the Maryland Piedmont Regional Curves which calculated an estimated bankfull area of 65.05 ft^2 (McCandless and Everett, 2002) for a 6.08 square mile (mi^2) drainage area. See Figure 4 below.



Equation: XS - Area = $17.42{*}DA^{0.73}$

Figure 4. Regional curve relating bankfull cross-sectional area (XS - Area) to drainage area (DA) for streams in the Piedmont physiographic province of Maryland.

The typical return period for a bankfull discharge in the Piedmont physiographic province of Maryland ranges from 1.26 years to 1.75 years, with an average return period of 1.5 years (McCandless and Everett, 2002). The estimated velocity and bankfull discharge from the regional curves is approximately 5.12 feet per second (ft/sec) and 333 cubic feet per second (cfs), respectively (McCandless and Everett, 2002). See Figure 5 below. Note that velocity was calculated from continuity (Abkf = Qbkf / ūbkf) where Abkf is the bankfull cross-sectional area, Qbkf is the bankfull discharge, and ūbkf is the mean velocity.



Equation: $Q = 84.56*DA^{0.76}$

Figure 5. Regional curve relating bankfull discharge (Q) to drainage area (DA) for streams in the Piedmont physiographic province of Maryland.

3.3.3.2 Tributary 2

The majority of the surveyed Tributary 2 stream reach is classified as a Rosgen F4 stream type. The lowest point of analysis at the end of the proposed LOD features a drainage area of approximately 1.59 square mile (1,017 acres). Tributary 2 is located in a confined alluvial valley (U-AL-FD). The wide valley has a gentle, down-valley elevational relief (slopes less than 3.0%). The unconfined valley allows the stream lateral migration room to a degree that the associated valley width ratio is greater than 7.0 times the width of bankfull. Characteristics typical of a F4 stream types include gravel-dominated, entrenched, meandering riffle/pool channel on low gradients with a high width/depth ratio. Rosgen F4 stream types are unstable stream types with lateral instability and high bank erosion rates.

The bankfull area (Abkf) was measured to be 27.05 square feet (ft^2) at the existing riffle. This field calculation was compared to the Maryland Piedmont Regional Curves which calculated an estimated bankfull area of 24.44 ft^2 (McCandless and Everett, 2002) for a 1.59 square mile (mi^2) drainage area. See Figure 4 above.

The estimated velocity and bankfull discharge from the regional curves is approximately 4.92 feet per second (ft/sec) and 120 cubic feet per second (cfs), respectively (McCandless and Everett, 2002). See Figure 5 above. Note that velocity was calculated from continuity (Abkf = Qbkf / ūbkf) where Abkf is the bankfull cross-sectional area, Qbkf is the bankfull discharge, and ūbkf is the mean velocity.

3.4 Sediment Competence Computations

Each tributary was evaluated for sediment competence at existing conditions to provide information on the trend of channel stability occurring at the evaluated reaches of Piney Run. Each tributary's results were analyzed and then a rating of stable, aggrading, or degrading could be selected. The full results of the sediment competence can be seen on Worksheet 3-14 in Appendix C.

3.4.1 Tributary 1 Sediment Competence

During the data analysis sediment competence was evaluated for both critical dimensionless shear stress using Dmax/D50 equation and critical dimensional shear stress. The critical dimensionless shear stress result provided the required mean depth and bankfull water surface slope required for entrainment of the largest particle in the bar sample. Tributary 1 existing condition exceeded both the mean depth and water surface slope suggested for entrainment showing the channel had the ability to transport the 42mm gravel (Dmax) of the bar and larger particles. Sediment competence was then evaluated using dimensional shear stress. This result suggested that the largest moveable particle initiated by bankfull flows was 65.32mm which is 155% larger than the existing Dmax. Both results of dimensionless and dimensional shear stress calculations indicate Tributary 1 is in a state of degradation.

3.4.2 Tributary 2 Sediment Competence

During the data analysis sediment competence was evaluated for both critical dimensionless shear stress using Dmax/D50 equation and critical dimensional shear stress. The critical dimensionless shear stress result provided the required mean depth and bankfull water surface slope required for entrainment of the largest particle in the bar sample. Tributary 2 existing condition exceeded both the mean depth and water surface slope suggested for entrainment showing the channel had the ability to transport the 51mm gravel (Dmax) of the bar and larger particles. Sediment competence was then evaluated using dimensional shear stress. This result suggested that the largest moveable particle initiated by bankfull flows was 111.9mm which is 219% larger than the existing Dmax. Both results of dimensionless and dimensional shear stress calculations indicate Tributary 2 is in a state of degradation.

3.5 FLOWSED Model Computations

FLOWSED/POWERSED Model was used to evaluate both tributaries for total sediment yield. The model helps quantify the accumulation of sediment in the reservoir on an annualized basis.

FLOWSED/POWERSED computations are provided in Appendix E. Given the distance from the closest USGS gage to the site as well as sediment transport disruption caused by the concrete box culverts at the downstream end of the tributaries, the actual values calculated are only approximations and may not reflect actual site conditions; however, the model appears to provide a close relationship to actual site conditions.

An analysis of anticipated sediment capacity was used to determine the volume of sediment yield within each reach. To analyze this capacity, “Poor” sediment values and “Poor” dimensionless sediment rating curves were used to generate sediment yield at existing condition, as this condition most closely reflects actual site conditions at the tributaries. The existing condition estimated 22,905 tons per year total of bedload and suspended sediment within the reach which correlates to be approximately 19,088 cubic yards per year. A full summary of FLOWSED/POWERSED analysis can be seen in Table 3 below.

Table 3. FLOWSED/POWERSED Analysis Summary

Reach	Annualized Total Sediment (Tons/Year)	Annualized Total Sediment Volume (CY/Year)*	Annualized Total Sediment Volume (Acre-feet)
Tributary 1	15,702	13,085	8.1
Tributary 2	6,474	5,395	3.3
TOTAL	22,176	18,480	11.4

*An approximation of 1.2 Tons/Cubic Yard was used to estimate Sediment Volume

The data collected from the FLOWSED and POWERSED model computations of the tributaries estimate a 7.7 square mile drainage area contributing 11.4 acre-feet per year to the reservoir. This data was then extrapolated to estimate a sediment contribution for the entire 10.1 square mile non-reservoir drainage area. The result produced an estimated rate of delivery of sediment from stream channels of approximately 15.4 acre-feet per year.

3.6 Edge of Stream Load Computations

In addition, AECOM used the *2019 Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated* (Maryland Department of the Environment, 2019) to develop estimates for distributed sediment loading from the watershed. The guidance document provides recommendations for total suspended solids loading rates based on the land cover in the watershed.

Table 4. Watershed Sediment Load (Edge of Stream)

Reach	Mixed Open Land Cover	Impervious Cover**	Total
Area (acres)	5,771	703	6,474
Unit Load Rate (lbs/acre/year)	1,414	8474	---
Load Rate (acre-feet/year)*	2.1	1.5	3.6

*An approximation of 1.2 Tons/Cubic Yard was used to estimate Sediment Volume
**Assumed to be 10.4% of the watershed per land cover within the watershed.

The combined total sediment estimated sedimentation rate is 19.0 acre-feet/year. It was previously noted that the average annualized loading based on a comparative analysis of the reservoir bathymetric volumes is 23 acre-feet/year which is higher than the estimated rate determined by looking at the sedimentation generation capability of the stream channels and watershed. Both methods of estimating the sediment load rate have inherent sources of error. Estimates of reservoir bathymetry is influenced aspects such as by the accuracy of the collection methods during each of the surveys compared, density of the data point cloud collected, interpolation methods, Estimates of sediment load rates from stream channel analysis are influenced by the ability of the selected channel cross sections analyzed to represent the stream system as whole, ability of generalized distributed sediment load rates to represent the loading from the watershed both spatially and temporally, and the ability of the selected stream gage data set to represent the discharge profile of the watershed to the reservoir. As both estimated load rates are significantly higher than the rate that appears to have been used during the original design, for the purposes of further analysis and discussion, an estimated load rate of 19 acre-feet/year is used.

The bathymetry data collected in October 2019 identified the Piney Run reservoir had a total available volume of approximately 5,311 acre-feet within the reservoir at EL. 524.0 feet. It is important to also note that as an NRCS Watershed Dam, there is a defined sediment accumulation pool for the reservoir at the bottom of the reservoir. In the case of Piney Run Reservoir, it is 339 acre-feet at approximate EL. 491.5 feet.

This estimated annualized delivery rate of 19.0 acre-feet would require approximately 280 years to fill the reservoir completely with sediment. As observed and previously discussed in this report, dams and reservoirs typically follows a non-uniform distribution of sediment. This observation means that the reservoir and subsequent Piney Run Dam may become non-functioning prior to reaching full capacity of sediment volume due to overaccumulation of sediment in certain locations such as in the upstream portions of the reservoir as well as in the coves. At the current delivery rate, the reservoir would have to be dredged completely of accumulated sediment approximately every 18 years to stay within the defined 339 acre-feet sediment accumulation pool. We note that the original design sediment accumulation pool was intended to have a 50-year design life yielding an average annual sediment loading allowance of approximately 6.8 acre-feet which is significantly less than the current loading as estimated.

3.7 Future Development Projections and Calculations

Analysis of the current bathymetry data show that since construction of the dam in 1974, a total approximate amount of 725 acre-feet of volume has been lost due to sediment deposition from the upstream sediment transport approximately 19 acre-feet per year. This is 386 acre-feet above the 339 acre-feet defined sediment accumulation pool for the reservoir. The current percent impervious based on land cover within the watershed is 10.4% and may increase to an ultimate imperviousness of up to 22.4% based on current zoning.

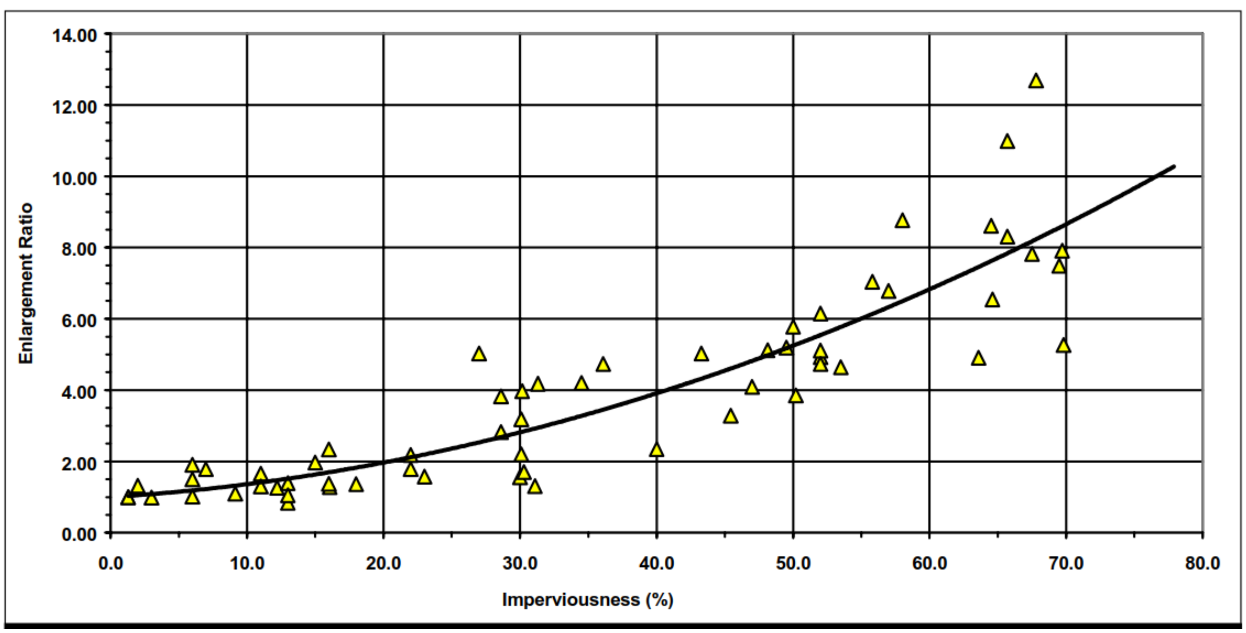


Figure 6. "Ultimate" channel enlargement as a function of impervious cover in alluvial streams in Maryland, Vermont, and Texas (MacRae and DeAndrea, 1999; and Brown and Claytor, 2000).

Using the ultimate channel enlargement ratio data as a function of impervious cover in alluvial streams we can expect an increase in channel size and subsequent sedimentation volume by 2.5 times the current rate. If we also assume that the sediment delivery rate would be a linear relationship with enlarging channel size this would equate to approximately 38.5 acre-feet of sediment being delivered to the reservoir on an annualized basis from stream degradation. In addition, the distributed watershed loading of sediment would increase from 3.6 to 4.9 acre-feet yield a total sediment load rate of 43.4 acre-feet per year. Using the new rate for accumulation of sediment this would lead to 122 years before the Piney Run reservoir would be completely full of sediment to EL. 524.0 feet. As previously stated, sediment deposition in dams and reservoirs typically demonstrates a non-uniform distribution of sediment. This observation means that the reservoir and subsequent Piney Run Dam may become non-functioning prior to reaching full capacity of sediment volume. At the projected ultimate percent impervious area of 22.4% the reservoir would have to be dredged completely of accumulated sediment every eight years to stay under the 339 acre-feet defined sediment accumulation pool.

These projections assume that no mitigation is performed in the watershed to address sediment loading rates. However, the County has put in place a Watershed Protection Plan for Piney Run watershed that prioritizes the watershed for implementation of both agricultural and restoration best management practices (BMPs) to control and limit erosion and sediment runoff into the tributaries of Piney Run. In addition, the County's stormwater management requirements have improved the management of runoff from developed sites over time and should help to mitigate increases in runoff and/or erosion resulting from future development, if any. Installing BMPs that improve the quality of both agricultural and developed property runoff as well as restoring and stabilizing stream channels will significantly reduce the annualized sediment loading rate by reducing erosion from both upland and in-stream portions of the watershed to Piney Run Dam and thus slow accumulation of sediment in the reservoir.

3.8 Effects of Excessive Sedimentation

As previously discussed, the current and projected future sediment load rates are significantly higher than it appears was intended by the original design. These higher load rates have resulted in sediment accumulation in the reservoir nearly twice that which was anticipated by the original design. Excessive reservoir sedimentation impacts all aspects of the reservoir's core functions including water supply, and recreation as well as affect the reservoir's aquatic environment.

- Water Supply – excessive sedimentation negatively impacts water supply by reducing the available reservoir volume in the normal pool possibly including within the projected water supply operating elevation band. This will reduce the safe yield of the reservoir and limit the amount of water than can be withdrawn.
- Recreation – excessive sedimentation negatively impacts recreation by reducing the accessible areas of the reservoir. Elevated sediment beds in the reservoir can render portions of the reservoir inaccessible by boat and due to the instability of accumulated sediment, unsafe to traverse by foot as well. This limits the areas that can used for boating, fishing and other acceptable aquatic recreation uses of the reservoir.
- Safety – accumulated sediment poses a life safety threat to the public. Sediment can be unstable, especially when accumulated to significant depths. People who try to traverse sediment on foot can get stuck and be engulfed leading to drowning.
- Aquatic Environment – there are several negative impacts of excessive sedimentation on the reservoir's aquatic environment. Sediment reduces the amount of dissolved oxygen in the water which negatively impacts fish populations in the reservoir. Accumulated sediment displaces reservoir water and reduces the depth of water making it susceptible to increased temperature fluctuations negatively impact aquatic life. With more sediment and less water, pollutant concentrations increase which, when discharged downstream can have negative impacts on the downstream riparian environment.

3.9 Conclusion

AECOM's field visit and geomorphic data assessment confirmed that the largest discharge contributing streams in the Piney Run watershed are impaired and contributing high volumes of sediment on an annualized basis. The presence of high bank erosional rates and near bank stressors is expected to increase as the watershed continues to develop. This development will likely lead to storm flows that produce more frequent bankfull events. This is expected to continue either until the stream reaches a state of equilibrium, which may be decades or even span multiple centuries or bank erosion is reduced by current accepted BMP methods, ordinances or mechanisms to offset sedimentation rates including but not limited to stream restoration, floodplain reconnection, and stream bank stabilization methods.

In order to bring the dam into compliance with the defined sediment accumulation pool (320 acre-feet maximum) the current rates of delivery would have to be maintained (i.e. no further stream degradation) and approximately all 725 acre-feet of sediment would need to be removed from the reservoir with the next scheduled maintenance to remove approximately 320 acre-feet of sediment occurring in approximately 20 years. This maintenance schedule may need to be more frequently if development continues toward the maximum allowed by zoning and no further efforts are made to reduce the sediment contribution of the Piney Run watershed. However, offsets to future development can be made by completing stream restoration and stabilization projects on upstream tributaries as well as continuing to enforce the County's existing stormwater management ordinance which requires development to treat up to 2.6 inches of runoff to the maximum extent practicable using small-scale stormwater management practices. These current and future County-lead efforts will have a positive effect on maintaining or perhaps reducing the future sediment delivery rate.

4. References

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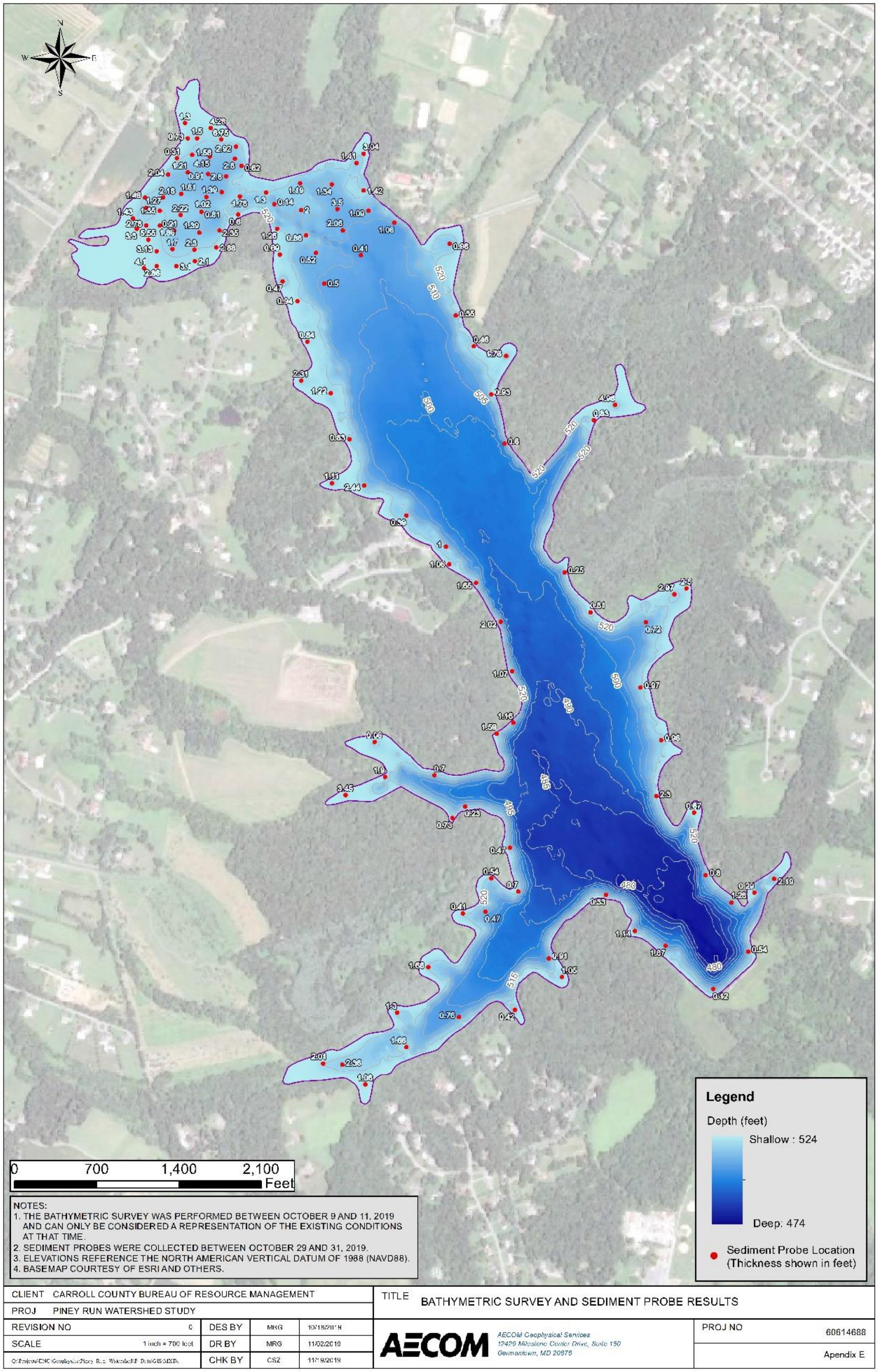
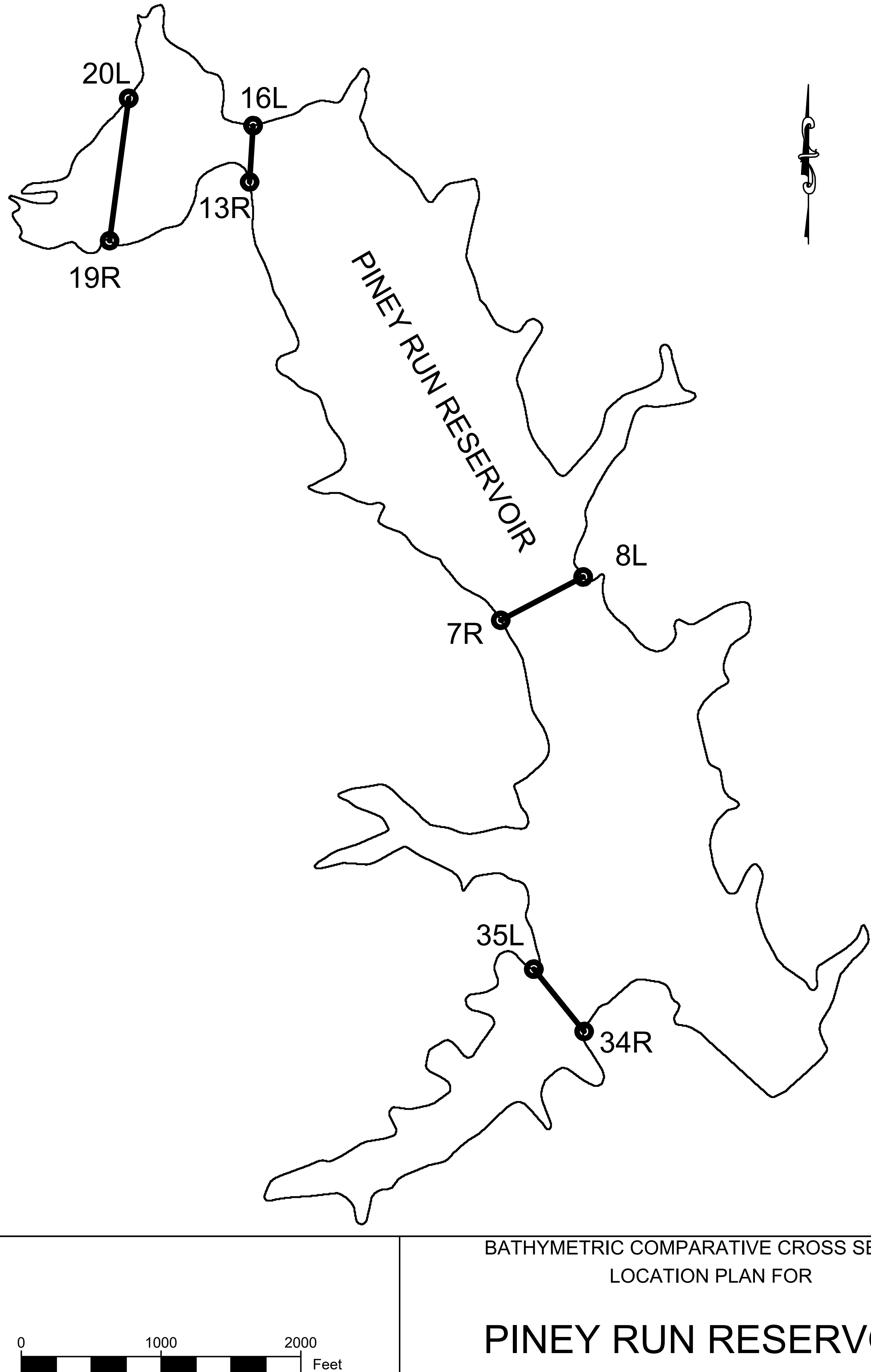
Appendix A: Bathymetry Map


N
S
W
E
0 700 1,400 2,100 Feet
Legend
Depth (feet)
Shallow : 524
Deep: 474
Sediment Probe Location (Thickness shown in feet)
NOTES:
1. THE BATHYMETRIC SURVEY WAS PERFORMED BETWEEN OCTOBER 9 AND 11, 2019 AND CAN ONLY BE CONSIDERED A REPRESENTATION OF THE EXISTING CONDITIONS AT THAT TIME.
2. SEDIMENT PROBES WERE COLLECTED BETWEEN OCTOBER 29 AND 31, 2019.
3. ELEVATIONS REFERENCE THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
4. BASEMAP COURTESY OF ESRI AND OTHERS.
CLIENT CARROLL COUNTY BUREAU OF RESOURCE MANAGEMENT
PROJ PINEY RUN WATERSHED STUDY
TITLE BATHYMETRIC SURVEY AND SEDIMENT PROBE RESULTS
REVISION NO 0
SCALE 1 inch = 700 feet
DES BY MRG
DR BY MRG 11/02/2019
CHK BY CSZ
AECOM
AECOM Geophysical Services
12420 Milestone Center Drive, Suite 150
Germantown, MD 20876
PROJ NO 60614688
Apendix E

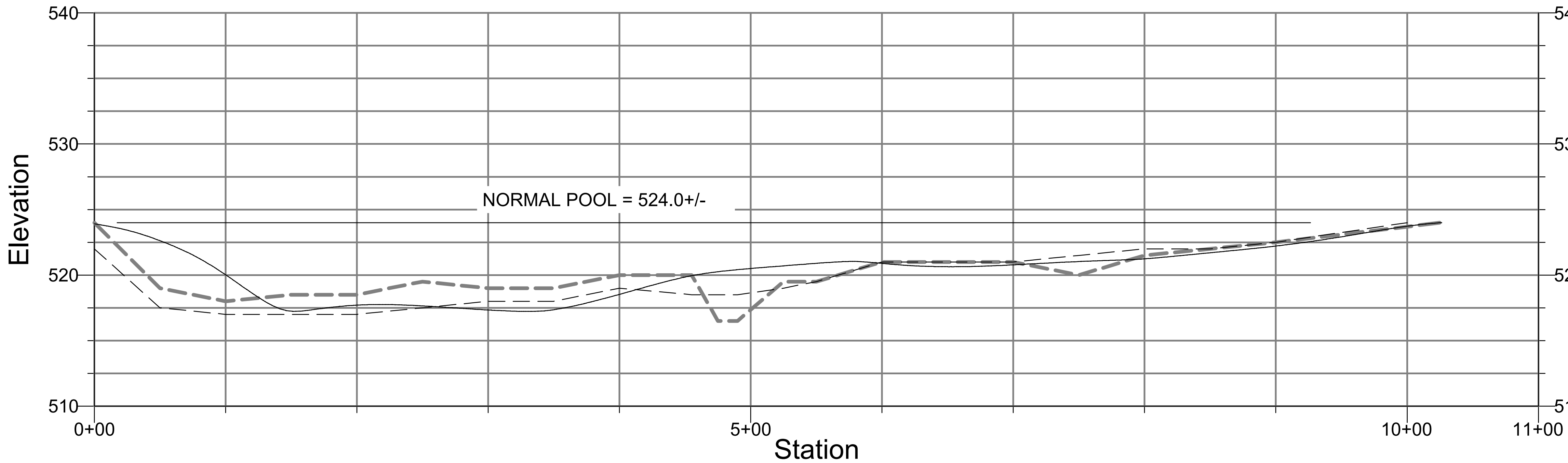


BATHYMETRIC COMPARATIVE CROSS SECTION
LOCATION PLAN FOR

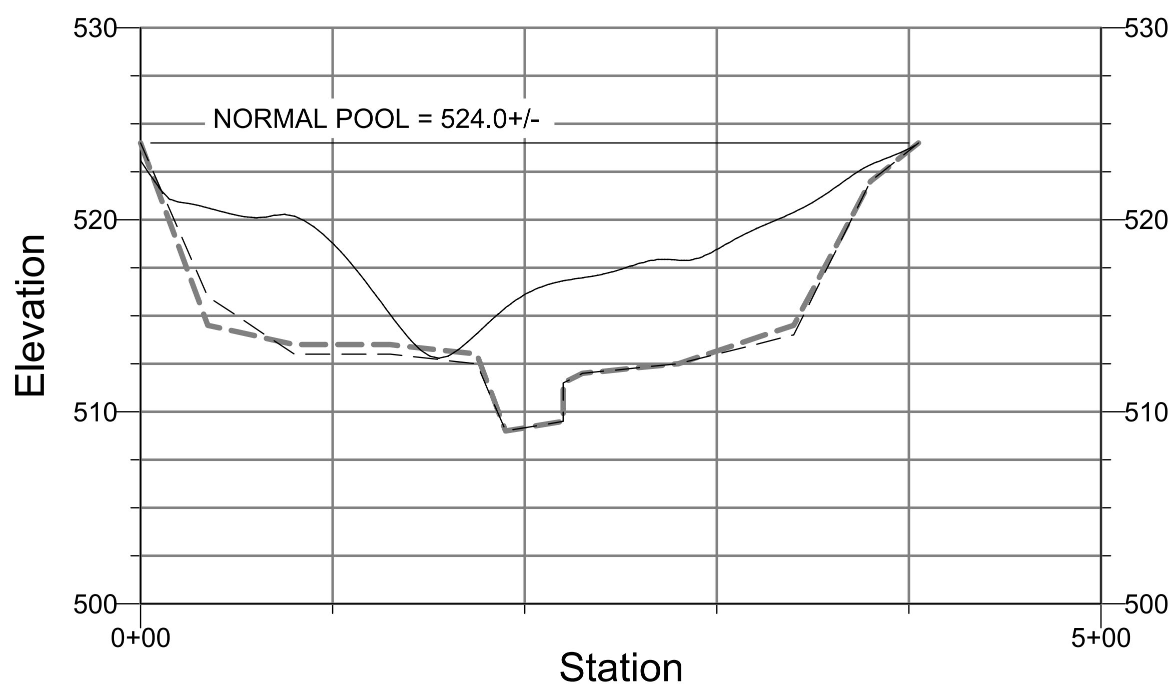
PINEY RUN RESERVOIR

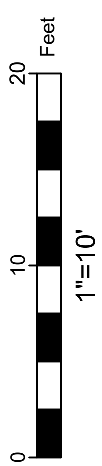
SYKESVILLE, MARYLAND

Section 20L-19R



Section16L-13R





NOTES:

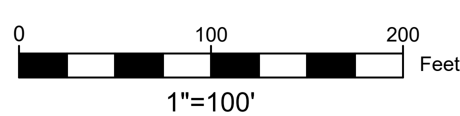
1. SECTIONS ARE TAKEN LOOKING LEFT TO RIGHT FACING DOWNSTREAM.
2. SECTION REFERENCES ARE TAKEN FROM SEDIMENT SURVEY BY GREENHORNE AND O'MARA COMPLETED 1988. DIRECTION ABBREVIATIONS 'L' AND 'R' ARE PROVIDED FOR ORIENTATION.
3. SECTION PROFILE FROM 1988 SURVEY FOR SECTION 8L-7R WAS NEARLY IDENTICAL TO 1974 SURVEY AND AS SUCH IS NOT SHOWN
4. SECTION PROFILE FROM 1988 SURVEY FOR SECTION 35L-34R WAS NOT PROVIDED.
5. SEDIMENT SURVEY BY MDE COMPLETED 2013 COULD NOT BE INCLUDED DUE TO LIMITED COVERAGE AND LACK OF DETAILED BATHYMETRY CONTOURING AVAILABLE.
6. DATUM REPORTED IS THE DATUM REPORTED IN THE PROJECT AS-BUILT PLANS.
7. * DENOTES THAT DEPICTION OF CROSS SECTION FROM 1988 SURVEY APPEARS TO HAVE BEEN OPPOSITE THAT OF THE REFERENCE MONUMENT ORIENTATION. CROSS SECTION ORIENTATION HAS BEEN CORRECTED PER THE ORIGINAL TOPOGRAPHY ON THIS DEPICTION.

LEGEND

1974 SURVEY

1988 SURVEY

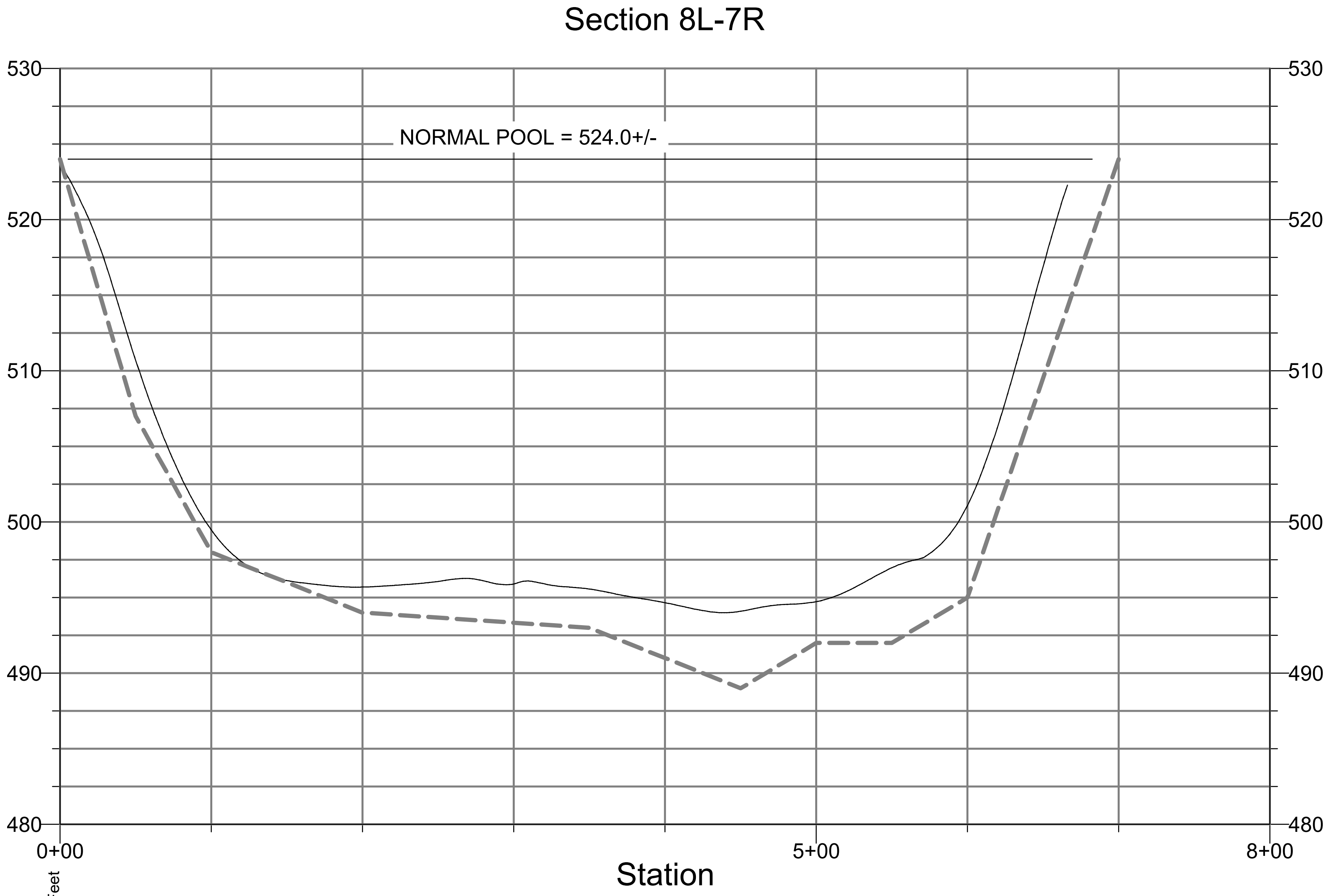
2019 SURVEY

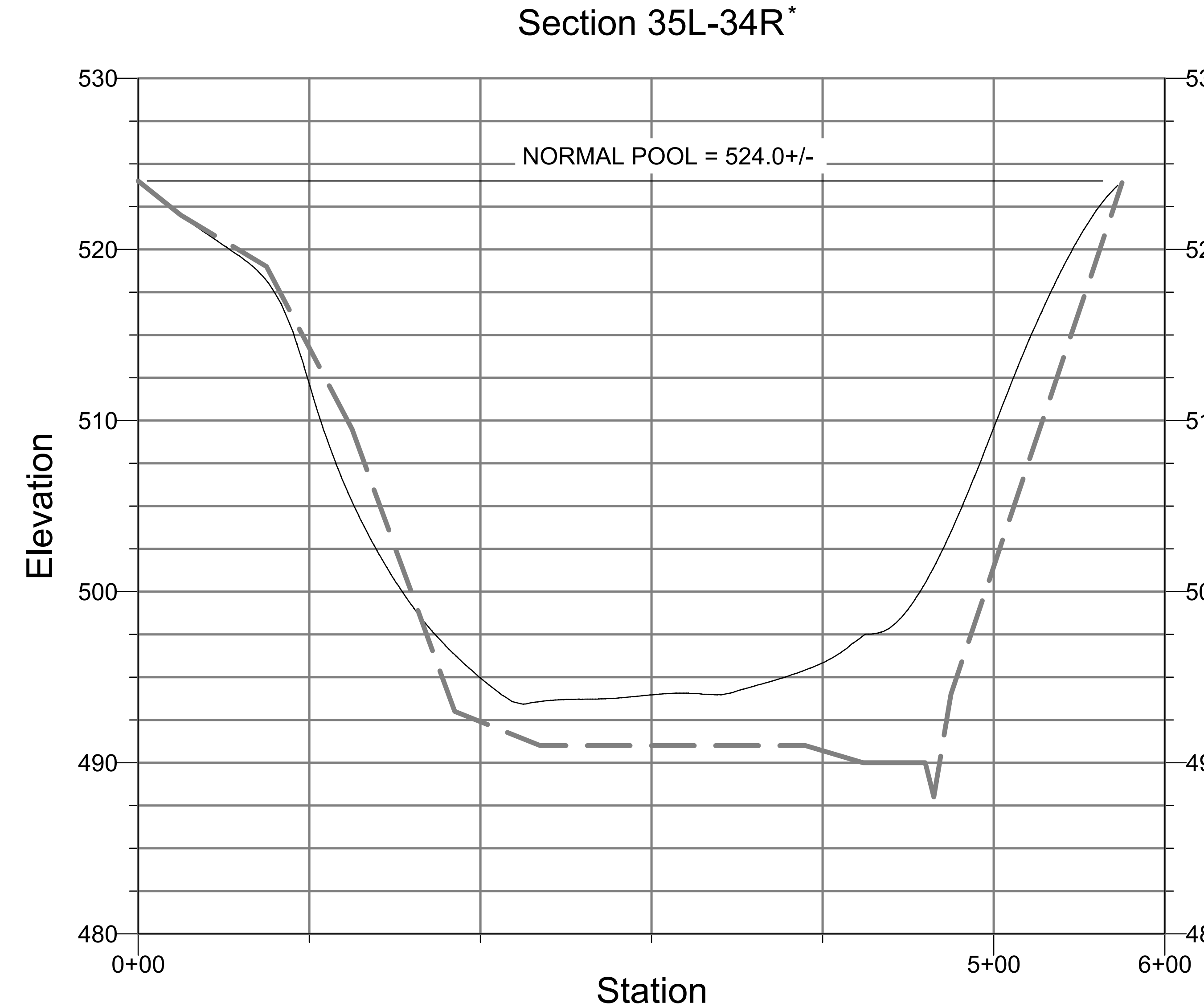


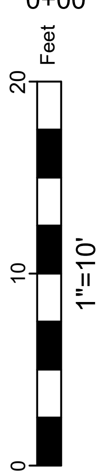
SELECTED BATHYMETRIC COMPARATIVE CROSS SECTIONS FOR

PINEY RUN RESERVOIR

SYKESVILLE, MARYLAND







NOTES:

1. SECTIONS ARE TAKEN LOOKING LEFT TO RIGHT FACING DOWNSTREAM.
2. SECTION REFERENCES ARE TAKEN FROM SEDIMENT SURVEY BY GREENHORNE AND O'MARA COMPLETED 1988. DIRECTION ABBREVIATIONS 'L' AND 'R' ARE PROVIDED FOR ORIENTATION.
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4. SECTION PROFILE FROM 1988 SURVEY FOR SECTION 35L-34R WAS NOT PROVIDED.
5. SEDIMENT SURVEY BY MDE COMPLETED 2013 COULD NOT BE INCLUDED DUE TO LIMITED COVERAGE AND LACK OF DETAILED BATHYMETRY CONTOURING AVAILABLE.
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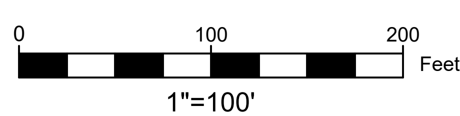
7. * DENOTES THAT DEPICTION OF CROSS SECTION FROM 1988 SURVEY APPEARS TO HAVE BEEN OPPOSITE THAT OF THE REFERENCE MONUMENT ORIENTATION. CROSS SECTION ORIENTATION HAS BEEN CORRECTED PER THE ORIGINAL TOPOGRAPHY ON THIS DEPICTION.

LEGEND

1974 SURVEY (heavy dashed line)

1988 SURVEY (light dashed line)

2019 SURVEY (solid line)



SELECTED BATHYMETRIC COMPARATIVE
CROSS SECTIONS FOR

PINEY RUN RESERVOIR

SYKESVILLE, MARYLAND

Appendix B: Existing Conditions Maps and Photographs

Photo 1: Tributary 1 Stream Overview – High bank erosion rates	
Photo 2: Tributary 1 Stream Overview – Mid channel bar formation from excess deposition	

Photo 3: Tributary 1 Left Bank – Vertical stream banks	
Photo 4: Tributary 1 Left Bank – Artificial bank stabilization on left bank with riprap	

Photo 5: Tributary 1 Stream Overview – High bank erosion rates	
Photo 6: Tributary 1 Stream Overview – Vertical left bank erosion	

Photo 7: Tributary 2 Stream Overview – High bank erosion rates	
Photo 8: Tributary 2 Stream Overview – Large debris accumulation in channel.	

Photo 9: Tributary 2 Right Bank – Failed artificial stream stabilization with riprap.	
Photo 10: Tributary 2 Left Bank – Transverse bar causing high bank erosion on left bank	

Photo 11: Tributary 2 Stream Overview – Riprap stabilization on left bank and high debris accumulation from undersized culvert.	
Photo 12: Tributary 2 Stream Overview – Significant woody debris accumulation and vertical right bank	

Appendix C: Geomorphic Assessment & Classification Data

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**60614688 - Piney Run Reservoir, Reach - Piney Run**			
Basin:	**Piney Run**	Drainage Area: **3891.2** acres	**6.08**	mi^2
Location:	**Piney Run Reservoir**			
Twp.&Rge:	**Eldersburg, Maryland**	Sec.&Qtr.:		
Cross-Section Monuments (Lat./Long.):	**39.405958 Lat / -77.000944 Long**		Date:	**11/05/19**
Observers:	**Brandon Alderman, Dan Wagner**		Valley Type:	U-AL-FD

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**34.15**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.65**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**56.41**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**20.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.83**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**100**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.93**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**16.9**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00373**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.14**	

Stream Type → **C 4** ← (See **Figure 2-14**)

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	60614688 - Piney Run Reservoir	Location:	Reach - Piney Run
Date:	11/5/2019	Stream Type:	C4
Valley Type:	U-AL-FD		
Observers:	Brandon Alderman/Dan Wagner	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	56.41	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.65	d_{bkf} (ft)
Bankfull Riffle WIDTH	34.15	W_{bkf} (ft)	Wetted PERIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	35.82	W_p (ft)
D_{84} at Riffle	43.13	Dia. (mm)	D_{84} (mm) / 304.8	0.14	D_{84} (ft)
Bankfull SLOPE	0.0037	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.57	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	11.06	R / D_{84}
Drainage Area	6.1	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	0.434	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log\{R / D_{84}\}] u^*$	3.81	ft / sec	214.74	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2} / n$; *n* = 0.029	4.24	ft / sec	239.01	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2} / n$; *n* = 0.019	6.47	ft / sec	364.86	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2} / n$; $n = 0.39*S^{0.38}*R^{-0.16}$; *n* = ; **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3		ft / sec		cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	3.99	ft / sec	224.86	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A; Return Period for Bankfull Discharge Q = 1.5 year	5.91	ft / sec	333.37	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	5.00	ft / sec	282.05	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**60614688 - Piney Run Reservoir**		Stream Type: **C 4**		
Location:	**Piney Run**		Valley Type: **U-AL-FD**		
Observers:	**Brandon Alderman, Dan Wagner**		Date: **11/05/2019**		
Enter Required Information for Existing Condition					
16.9	D_{50}	Median particle size of riffle bed material (mm)			
7.5	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.138	D_{max}	Largest particle from bar sample (ft)	**42**	**(mm)**	304.8 mm/ft
0.00308	S	Existing bankfull water surface slope (ft/ft)			
1.65	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
2.25	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
2.49	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
0.017	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**2**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
1.26	**d**	Required bankfull mean depth (ft) $d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$ (use D_{max} in ft)			
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
0.00236	**S**	Required bankfull water surface slope (ft/ft) $S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$ (use D_{max} in ft)			
		Check: ☐ Stable ☐ Aggrading ☑ Degrading			

Sediment Competence Using Dimensional Shear Stress		
0.317		Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields **23.56**	CO **65.32**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **0.552**	CO **0.174**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **2.87**	CO **0.91**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields **0.0054**	CO **0.0017**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth
		Check: ☐ Stable ☐ Aggrading ☑ Degrading

RIVERMORPH CROSS SECTION SUMMARY

River Name: 60614688 - Piney Run Reservoir
Reach Name: Piney Run
Cross Section Name: XS-01 Riffle
Survey Date: 11/05/2019

Cross Section Data Entry

BM Elevation: 100 ft
Backsight Rod Reading: 5 ft

TAPE	FS	ELEV	NOTE
0	5.37	99.63	LEP
2.9	5.36	99.64	
6	5.28	99.72	
10	5.25	99.75	
13	5.16	99.84	
16.2	4.91	100.09	
19	5.01	99.99	
19.8	5.01	99.99	TOB
20.7	5.9	99.1	
20.2	6.62	98.38	BKF
20.6	7.29	97.71	
20.7	7.56	97.44	
21	7.76	97.24	
21.2	7.9	97.1	IB
21.9	8.48	96.52	LEW
22.5	8.93	96.07	TOE
23.6	9.09	95.91	
24.7	9.35	95.65	
26.4	9.43	95.57	TW
28.4	9.21	95.79	
31	9.1	95.9	
32.2	9.1	95.9	
34.8	9.13	95.87	
37.2	8.83	96.17	
39	8.65	96.35	
41	8.45	96.55	REW
42.3	8.33	96.67	
43.4	7.98	97.02	
44.4	7.91	97.09	
44.8	7.85	97.15	IB
45	7.55	97.45	
45.9	6.87	98.13	
47.7	6.58	98.42	
50.7	6.76	98.24	
52.2	6.92	98.08	
54.9	6.59	98.41	
56.7	6.54	98.46	
57.8	6.59	98.41	BKF
61.2	5.5	99.5	
63.5	4.9	100.1	
66.9	4.8	100.2	REP

Cross Sectional Geometry

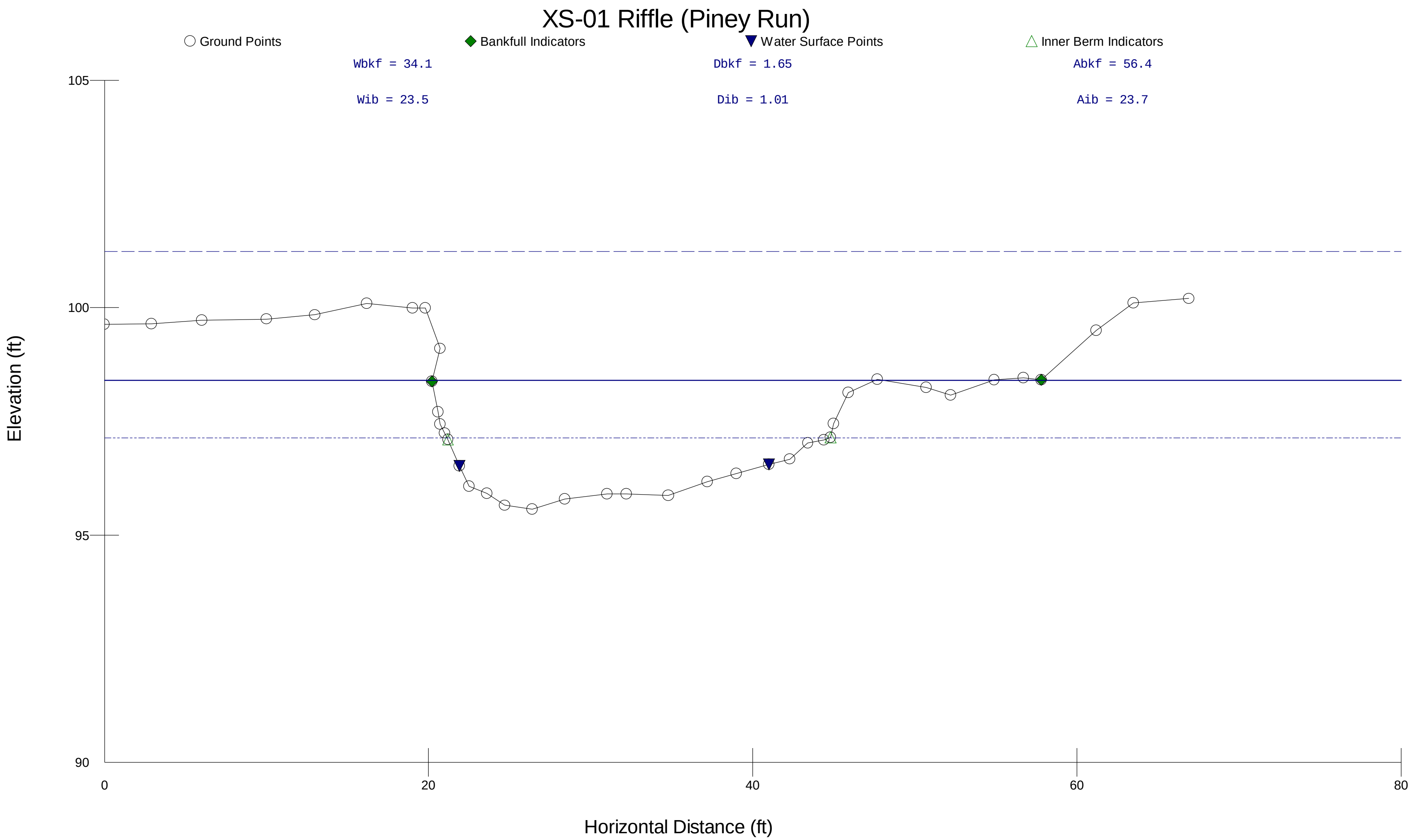
	Channel	Left	Right
Floodprone Elevation (ft)	101.23	101.23	101.23

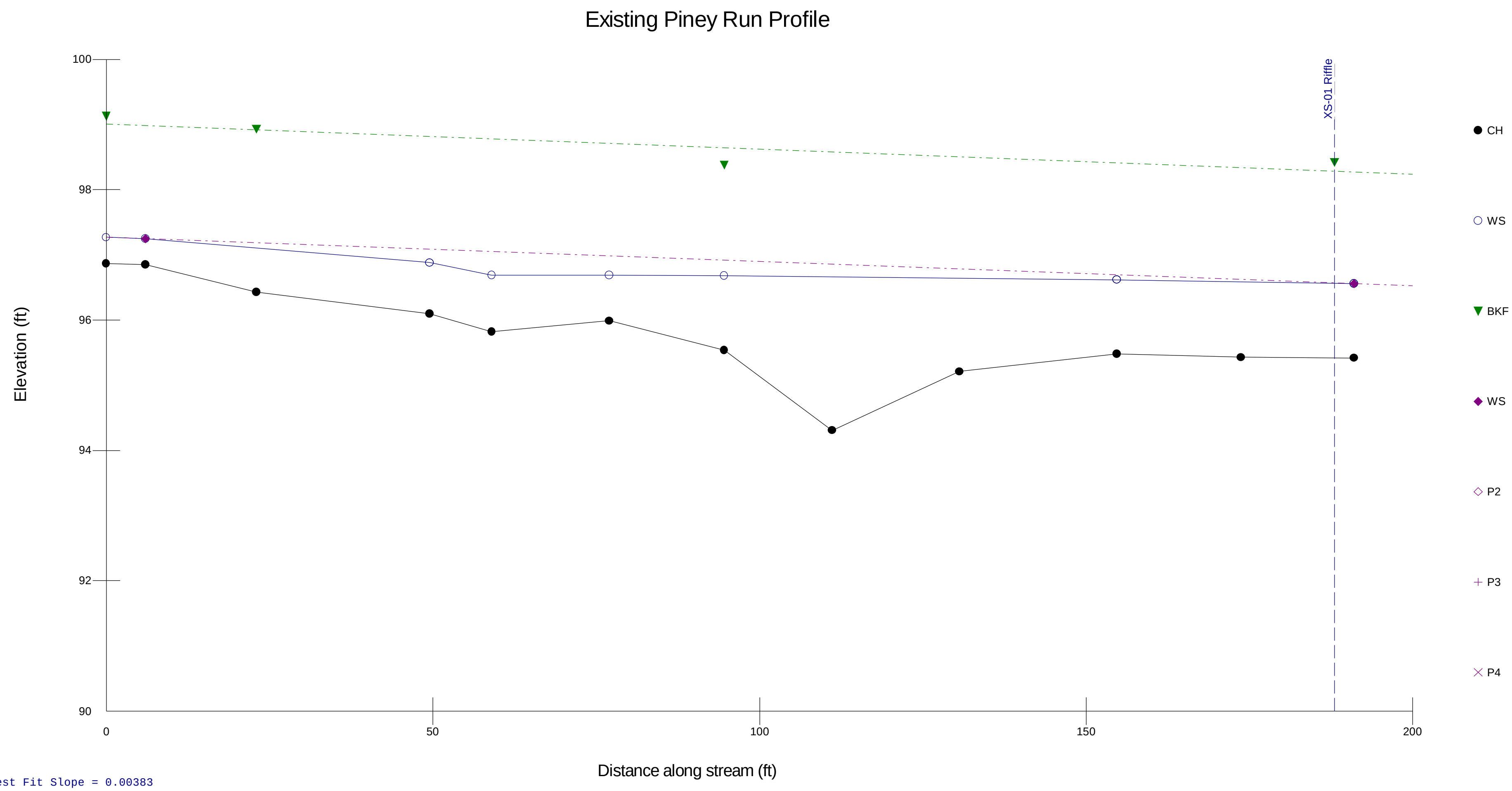
Bankfull Elevation (ft)	98.4	98.4	98.4
Floodprone Width (ft)	100	-----	-----
Bankfull Width (ft)	34.15	17.08	17.53
Entrenchment Ratio	2.93	-----	-----
Mean Depth (ft)	1.65	2.4	0.9
Maximum Depth (ft)	2.83	2.83	2.22
Width/Depth Ratio	20.7	7.12	19.48
Bankfull Area (sq ft)	56.41	40.97	15.43
Wetted Perimeter (ft)	35.82	20.44	19.82
Hydraulic Radius (ft)	1.57	2	0.78
Begin BKF Station	20.21	20.21	37.29
End BKF Station	54.82	37.29	54.82

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00373	0	0
Shear Stress (lb/sq ft)	0.37		
Movable Particle (mm)	72.5		


XS-01 Riffle (Piney Run)
Ground Points
Bankfull Indicators
Water Surface Points
Inner Berm Indicators
Wbkf = 34.1
Dbkf = 1.65
Abkf = 56.4
Wib = 23.5
Dib = 1.01
Aib = 23.7
Elevation (ft)
105
100
95
90
0
20
40
60
80
Horizontal Distance (ft)



BKF Best Fit Slope = 0.00383
WS Best Fit Slope = 0.00373

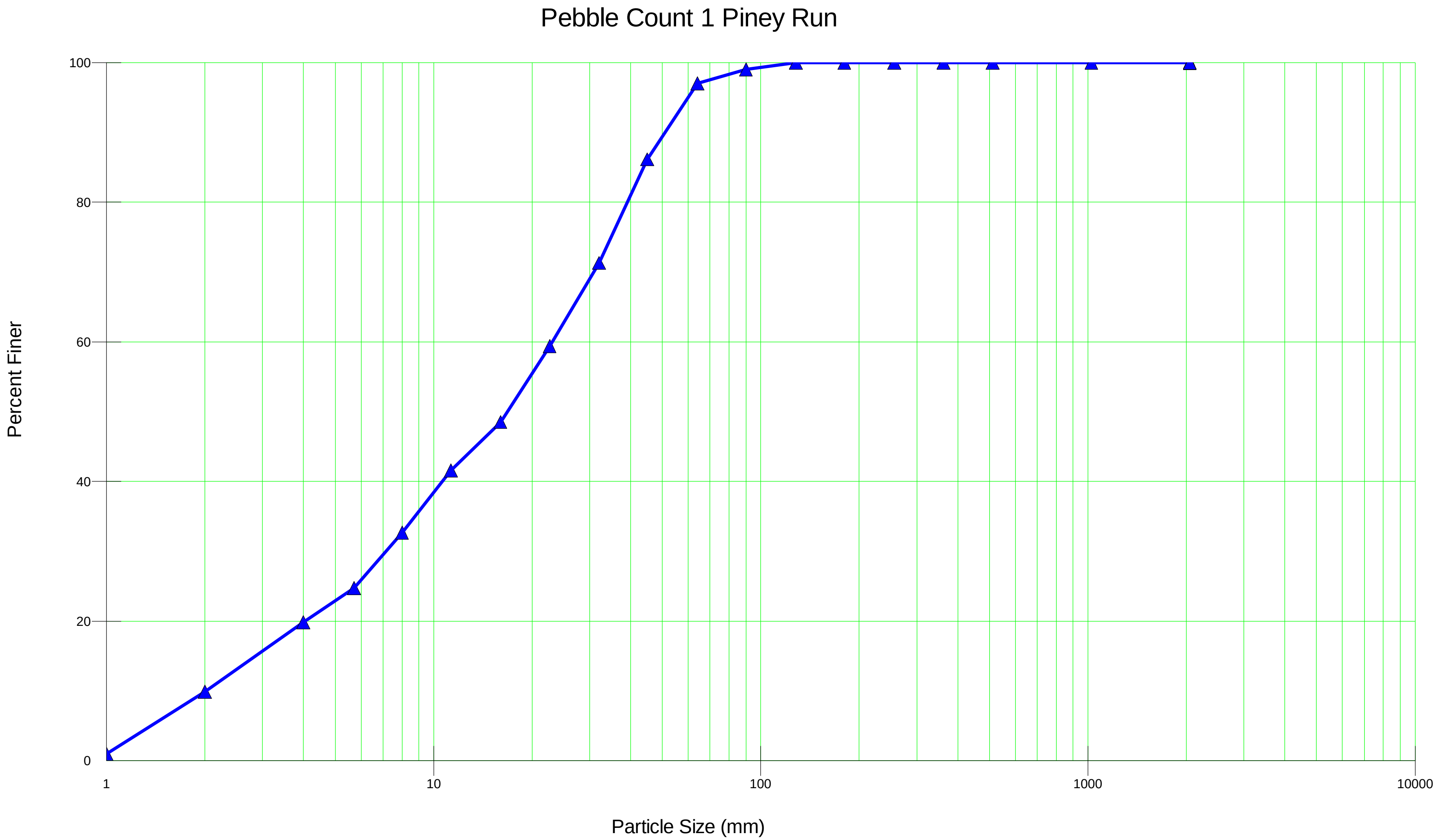
RIVERMORPH PARTICLE SUMMARY

River Name:	60614688 - Piney Run Reservoir
Reach Name:	Piney Run
Sample Name:	Pebble Count 1 Piney Run
Survey Date:	11/05/2019

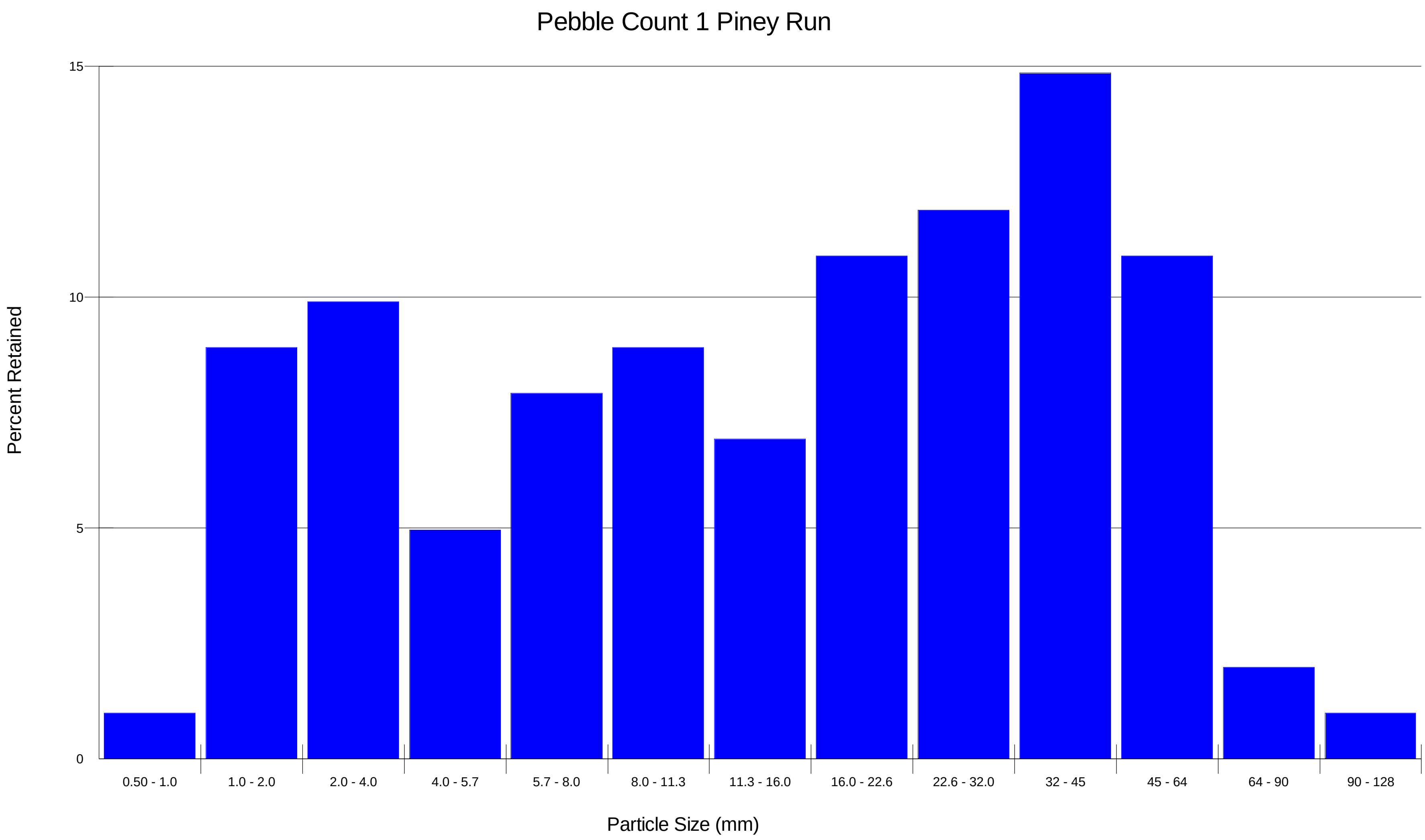
Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	1	0.99	0.99
1.0 - 2.0	9	8.91	9.90
2.0 - 4.0	10	9.90	19.80
4.0 - 5.7	5	4.95	24.75
5.7 - 8.0	8	7.92	32.67
8.0 - 11.3	9	8.91	41.58
11.3 - 16.0	7	6.93	48.51
16.0 - 22.6	11	10.89	59.41
22.6 - 32.0	12	11.88	71.29
32 - 45	15	14.85	86.14
45 - 64	11	10.89	97.03
64 - 90	2	1.98	99.01
90 - 128	1	0.99	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	3.23
D35 (mm)	8.86
D50 (mm)	16.9
D84 (mm)	43.13
D95 (mm)	60.46
D100 (mm)	128
Silt/Clay (%)	0
Sand (%)	9.9
Gravel (%)	87.13
Cobble (%)	2.97
Boulder (%)	0
Bedrock (%)	0

Total Particles = 101.



Pebble Count 1 Piney Run
Percent Finer
0
20
40
60
80
100
1
10
100
1000
10000
Particle Size (mm)


Pebble Count 1 Piney Run
Percent Retained
15
10
5
0
0.50 - 1.0
1.0 - 2.0
2.0 - 4.0
4.0 - 5.7
5.7 - 8.0
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
Particle Size (mm)

RIVERMORPH PARTICLE SUMMARY

River Name: 60614688 - Piney Run Reservoir
Reach Name: Piney Run
Sample Name: Bar Sample 1 Piney Run
Survey Date: 11/05/2019

SIEVE (mm)	NET WT
31.5	0.695
16	5.61
8	6.205
4	5.66
2	3.68
PAN	4.91

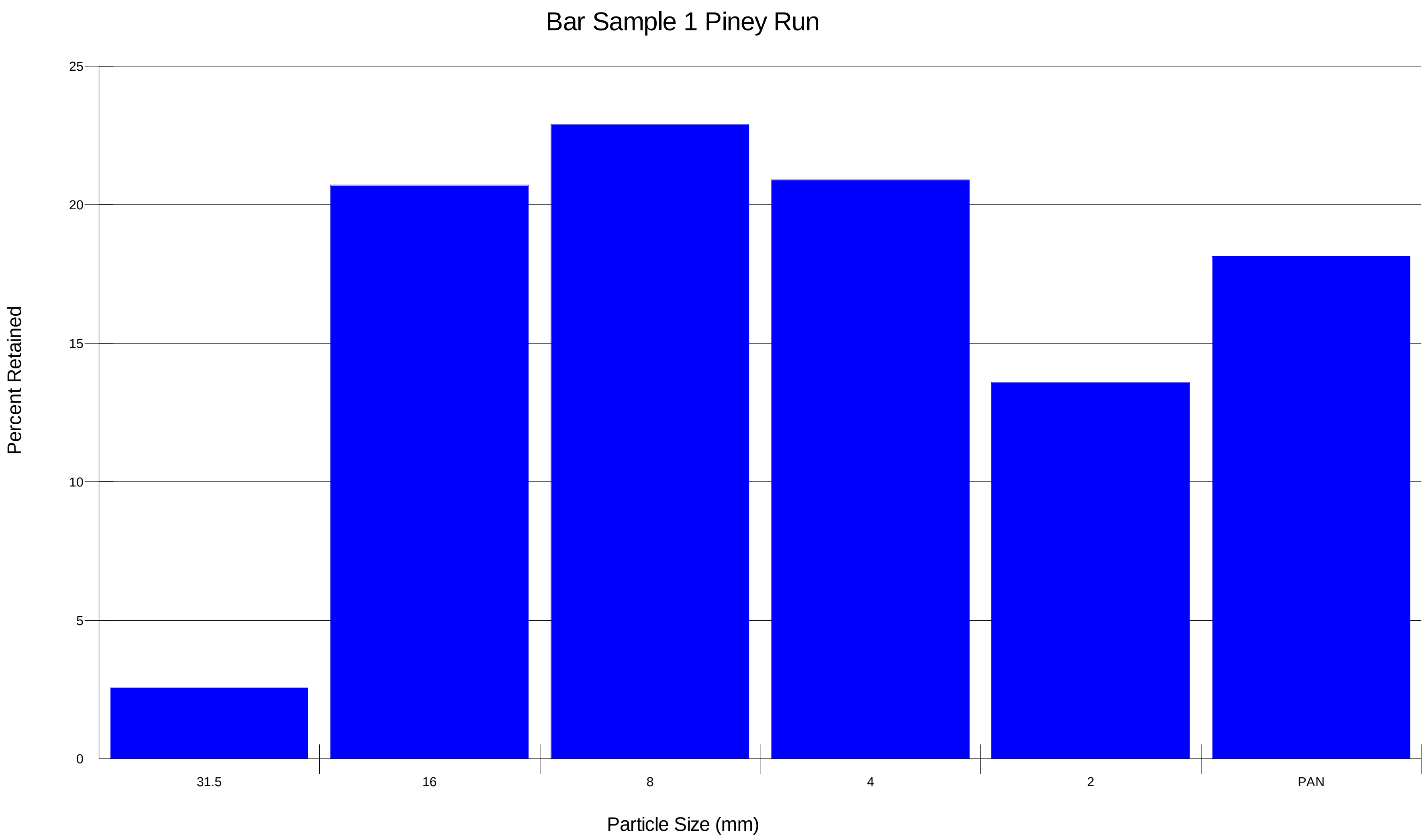
D16 (mm)	0
D35 (mm)	4.63
D50 (mm)	7.5
D84 (mm)	22.36
D95 (mm)	30.59
D100 (mm)	42
Silt/Clay (%)	0
Sand (%)	18.12
Gravel (%)	81.88
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

Total Weight = 27.0900.

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	42	0.2
Particle 2:	34	0.13

Bar Sample 1 Piney Run
Percent Finer
0
20
40
60
80
100
1
10
100
Particle Size (mm)


Bar Sample 1 Piney Run
Percent Retained
25
20
15
10
5
0
31.5
16
8
4
2
PAN
Particle Size (mm)

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**60614688 - Piney Run Reservoir, Reach - UNT of Piney Run**
Basin:	**Piney Run** Drainage Area: **1017.6** acres **1.59** mi^2
Location:	**Piney Run Reservoir**
Twp.&Rge:	**Eldersburg, Maryland** Sec.&Qtr.:
Cross-Section Monuments (Lat./Long.):	**39.409983 Lat / -76.993695 Long** Date: **11/06/19**
Observers:	**Brandon Alderman/Dan Wagner** Valley Type: U-AL-FD

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**15.08**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.79**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**27.05**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**8.42**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.99**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**37**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.45**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**19.3**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0059**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.26**	

Stream Type **F 4** (See **Figure 2-14**)

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	60614688 - Piney Run Reservoir	Location:	Reach - UNT of Piney Run
Date:	11/8/2019	Stream Type: F4	Valley Type: U-AL-FD
Observers:	Brandon Alderman/Dan Wagner	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	27.05	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.79	d_{bkf} (ft)
Bankfull Riffle WIDTH	15.08	W_{bkf} (ft)	Wetted PERIMETER ~ (2 * d_{bkf}) + W_{bkf}	16.77	W_p (ft)
D_{84} at Riffle	55.77	Dia. (mm)	D_{84} (mm) / 304.8	0.18	D_{84} (ft)
Bankfull SLOPE	0.0059	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.61	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	8.80	R / D_{84}
Drainage Area	1.6	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	0.553	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log \{ R / D_{84} \}] u^*$	4.53	ft / sec	122.49	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49 * R^{2/3} * S^{1/2} / n$ *n* = 0.031	5.07	ft / sec	137.04	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49 * R^{2/3} * S^{1/2} / n$ *n* = 0.041	3.83	ft / sec	103.60	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49 * R^{2/3} * S^{1/2} / n$ $n = 0.39 * S^{0.38} * R^{-0.16}$ *n* = Note: This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3		ft / sec		cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	4.97	ft / sec	134.34	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.5 year	4.45	ft / sec	120.29	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	5.00	ft / sec	135.35	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**60614688 - Piney Run Reservoir**		Stream Type:	**F 4**
Location:	**UNT of Piney Run**		Valley Type:	**U-AL-FD**
Observers:	**Brandon Alderman/Dan Wagner**		Date:	**11/06/2019**

Enter Required Information for Existing Condition

19.3	D_{50}	Median particle size of riffle bed material (mm)			
9.6	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.167	D_{max}	Largest particle from bar sample (ft)	**51**	**(mm)**	304.8 mm/ft
0.00590	S	Existing bankfull water surface slope (ft/ft)			
1.79	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

2.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
2.64	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
0.016	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**2**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.76	d	Required bankfull mean depth (ft)	$d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$	(use D_{max} in ft)

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.00250	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☑ Degrading

Sediment Competence Using Dimensional Shear Stress

0.659		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields **50.49**	CO **111.9**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **0.665**	CO **0.227**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **1.81**	CO **0.62**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields **0.0060**	CO **0.0020**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Check: ☐ Stable ☐ Aggrading ☑ Degrading

RIVERMORPH CROSS SECTION SUMMARY

River Name: 60614688 - Piney Run Reservoir
Reach Name: UNT of Piney Run
Cross Section Name: XS-02 Riffle
Survey Date: 11/06/2019

Cross Section Data Entry

BM Elevation: 100 ft
Backsight Rod Reading: 5 ft

TAPE	FS	ELEV	NOTE
0	5.94	99.06	LEP
2	5.89	99.11	
5	5.85	99.15	
8	5.75	99.25	
10.2	5.83	99.17	
10.6	6.16	98.84	
12	6.24	98.76	
13	6.33	98.67	
14.6	6.34	98.66	
15.1	6.45	98.55	BKF
15.7	6.9	98.1	
16.1	7.07	97.93	
16.5	7.86	97.14	IB
16.7	8.01	96.99	
17.2	8.37	96.63	
17.5	8.73	96.27	LEW
17.9	8.82	96.18	
18.4	9.1	95.9	TOE
19.2	9.08	95.92	
20	9.22	95.78	
20.8	9.37	95.63	TW
21.2	9.32	95.68	
21.6	9.21	95.79	
22	9.07	95.93	
22.4	9.05	95.95	
22.8	9	96	
22.9	8.85	96.15	
23.3	8.74	96.26	REW
23.7	8.65	96.35	
24.6	8.4	96.6	
25.3	8.17	96.83	
25.8	8	97	
26.4	7.84	97.16	IB
27	7.66	97.34	
28	7.17	97.83	Edge of Deposition
30	6.32	98.68	BKF
31.3	5.71	99.29	
33	5.69	99.31	
34	5.7	99.3	
35	5.65	99.35	
37	5.7	99.3	REP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	101.61	101.61	101.61

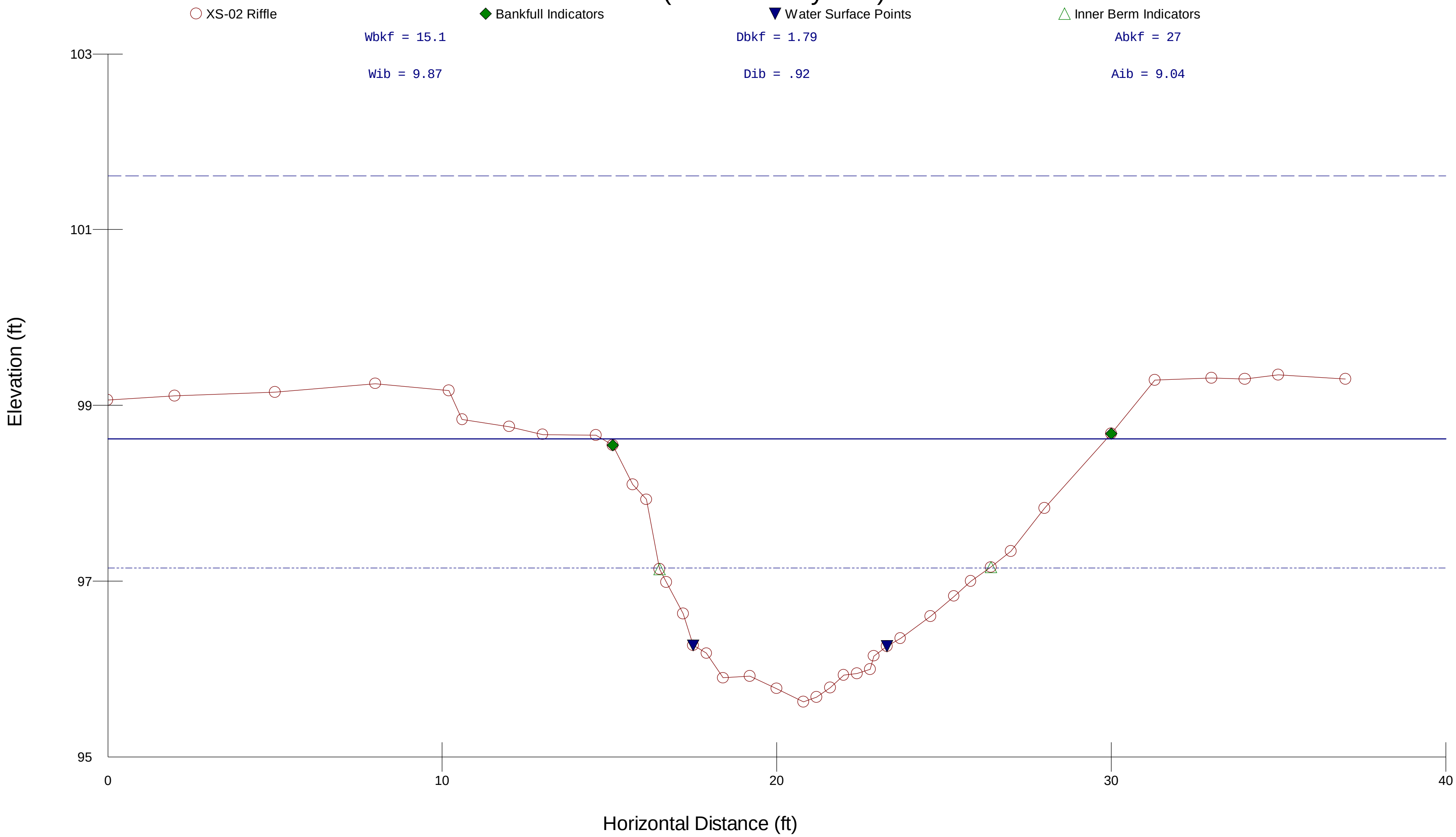
Bankfull Elevation (ft)	98.62	98.62	98.62
Floodprone Width (ft)	50	-----	-----
Bankfull Width (ft)	15.08	6.65	8.43
Entrenchment Ratio	3.32	-----	-----
Mean Depth (ft)	1.79	2.04	1.6
Maximum Depth (ft)	2.99	2.99	2.88
Width/Depth Ratio	8.42	3.26	5.27
Bankfull Area (sq ft)	27.05	13.55	13.5
Wetted Perimeter (ft)	16.77	10.66	11.87
Hydraulic Radius (ft)	1.61	1.27	1.14
Begin BKF Station	14.78	14.78	21.43
End BKF Station	29.86	21.43	29.86

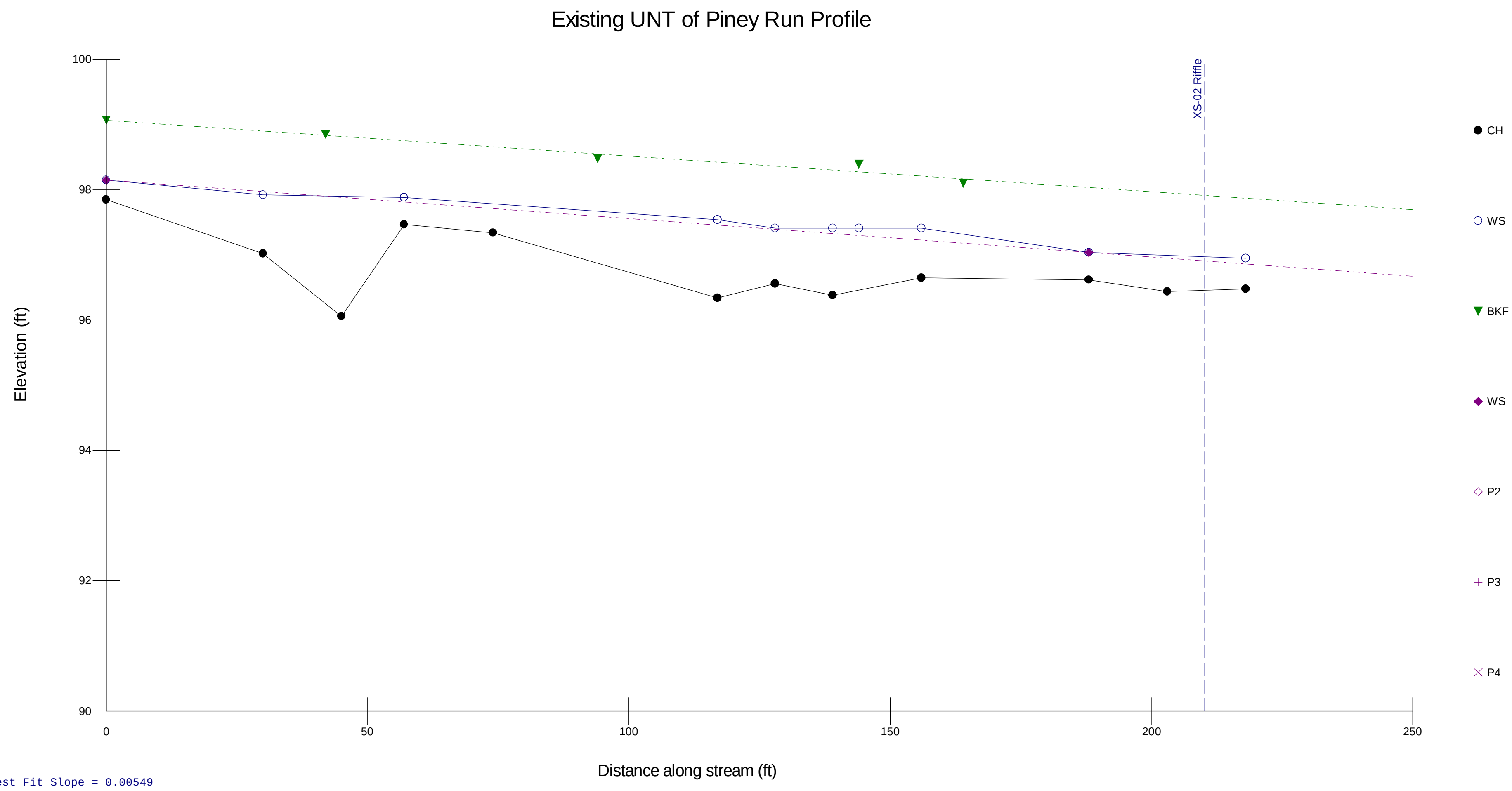
Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.00509	0	0
Shear Stress (lb/sq ft)	0.51		
Movable Particle (mm)	92.8		

XS-02 Riffle (UNT of Piney Run)





BKF Best Fit Slope = 0.00549
WS Best Fit Slope = 0.00590

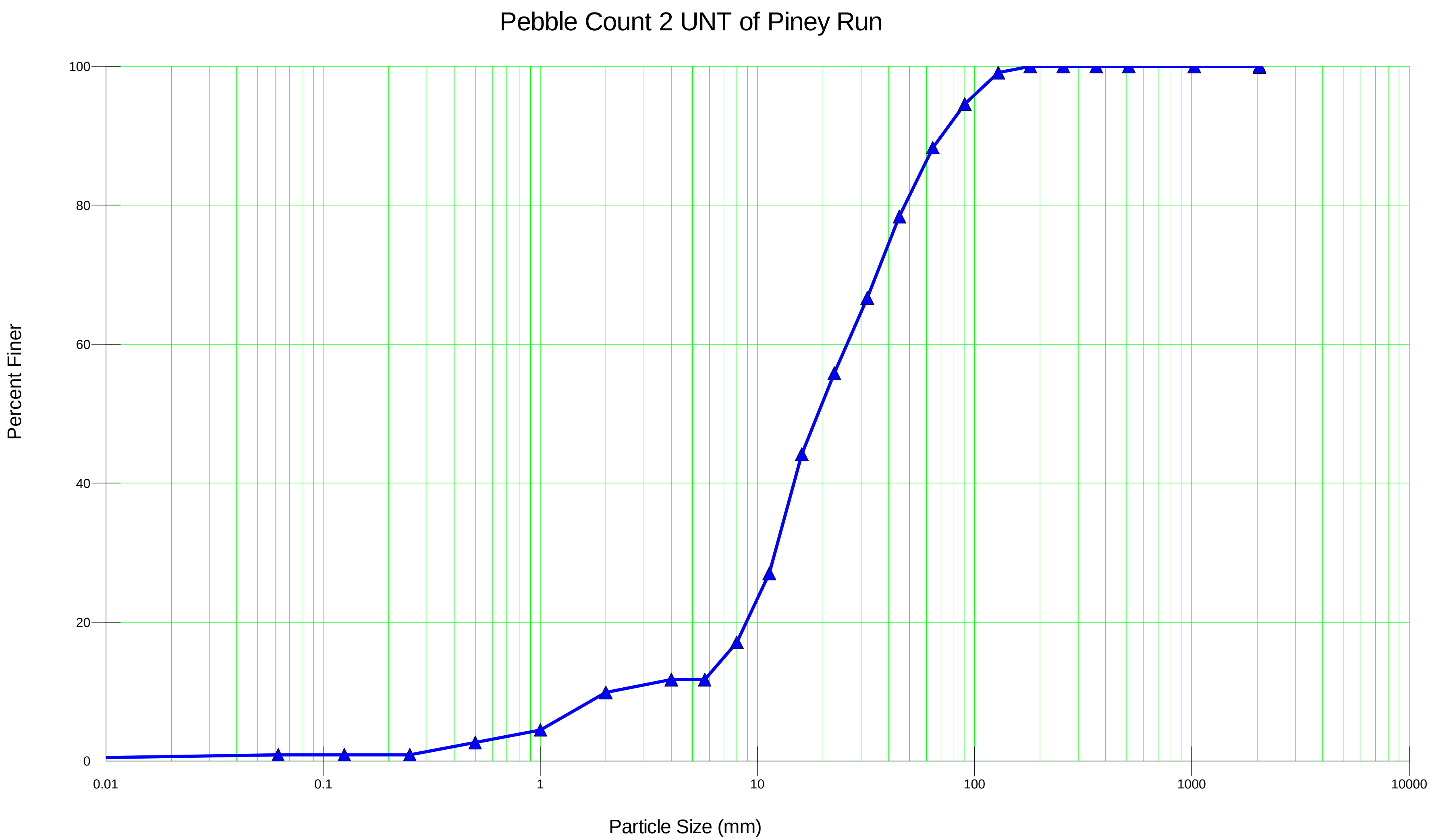
RIVERMORPH PARTICLE SUMMARY

River Name: 60614688 - Piney Run Reservoir
Reach Name: UNT of Piney Run
Sample Name: Pebble Count 2 UNT of Piney Run
Survey Date: 11/06/2019

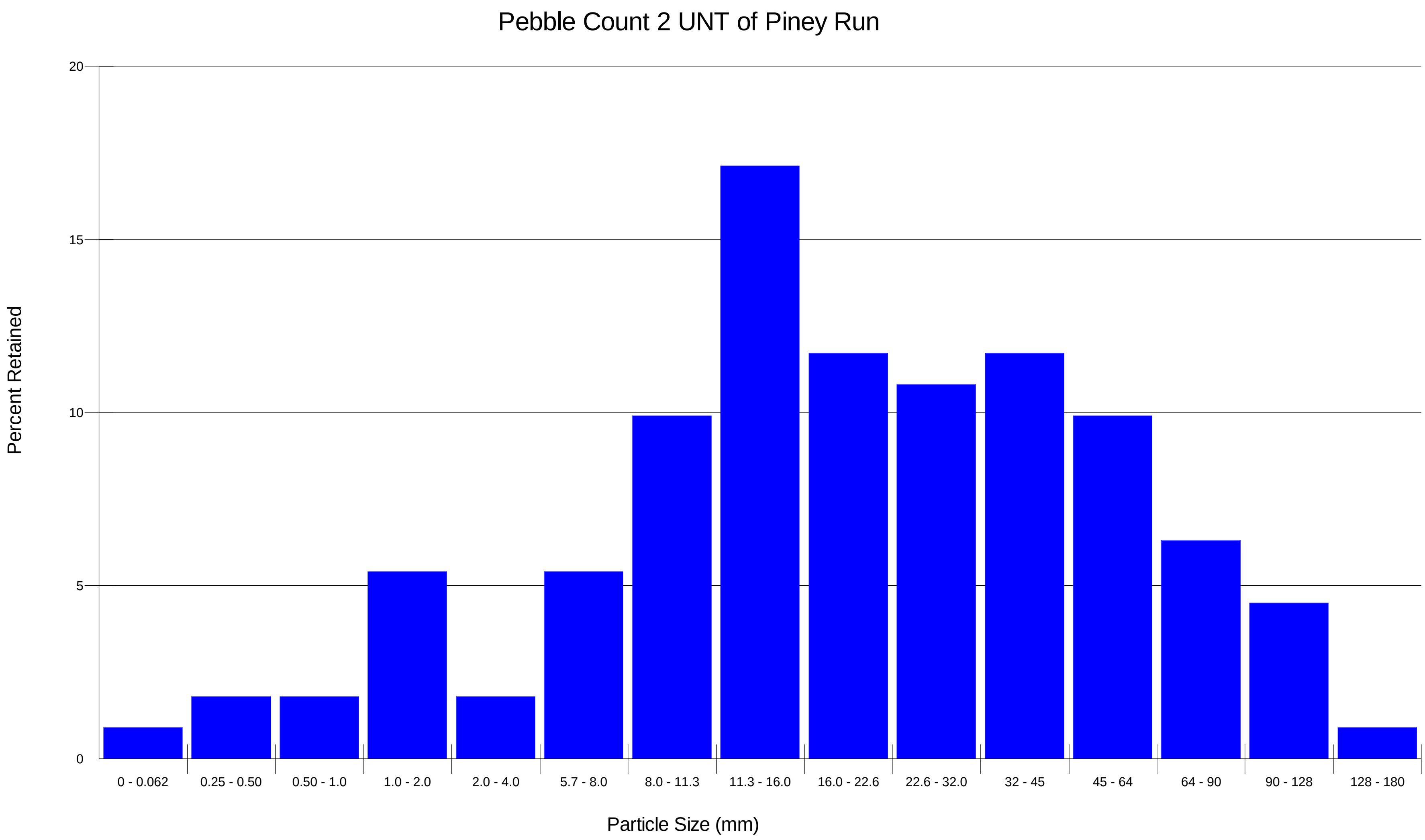
Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	1	0.90	0.90
0.062 - 0.125	0	0.00	0.90
0.125 - 0.25	0	0.00	0.90
0.25 - 0.50	2	1.80	2.70
0.50 - 1.0	2	1.80	4.50
1.0 - 2.0	6	5.41	9.91
2.0 - 4.0	2	1.80	11.71
4.0 - 5.7	0	0.00	11.71
5.7 - 8.0	6	5.41	17.12
8.0 - 11.3	11	9.91	27.03
11.3 - 16.0	19	17.12	44.14
16.0 - 22.6	13	11.71	55.86
22.6 - 32.0	12	10.81	66.67
32 - 45	13	11.71	78.38
45 - 64	11	9.91	88.29
64 - 90	7	6.31	94.59
90 - 128	5	4.50	99.10
128 - 180	1	0.90	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	7.52
D35 (mm)	13.49
D50 (mm)	19.3
D84 (mm)	55.77
D95 (mm)	93.45
D100 (mm)	179.99
Silt/Clay (%)	0.9
Sand (%)	9.01
Gravel (%)	78.38
Cobble (%)	11.71
Boulder (%)	0
Bedrock (%)	0

Total Particles = 111.



Pebble Count 2 UNT of Piney Run
Percent Finer
100
80
60
40
20
0
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)


Pebble Count 2 UNT of Piney Run
Percent Retained
20
15
10
5
0
0 - 0.062
0.25 - 0.50
0.50 - 1.0
1.0 - 2.0
2.0 - 4.0
5.7 - 8.0
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
Particle Size (mm)

RIVERMORPH PARTICLE SUMMARY

River Name:	60614688 - Piney Run Reservoir
Reach Name:	UNT of Piney Run
Sample Name:	Bar Sample 2 UNT of Piney Run
Survey Date:	11/06/2019

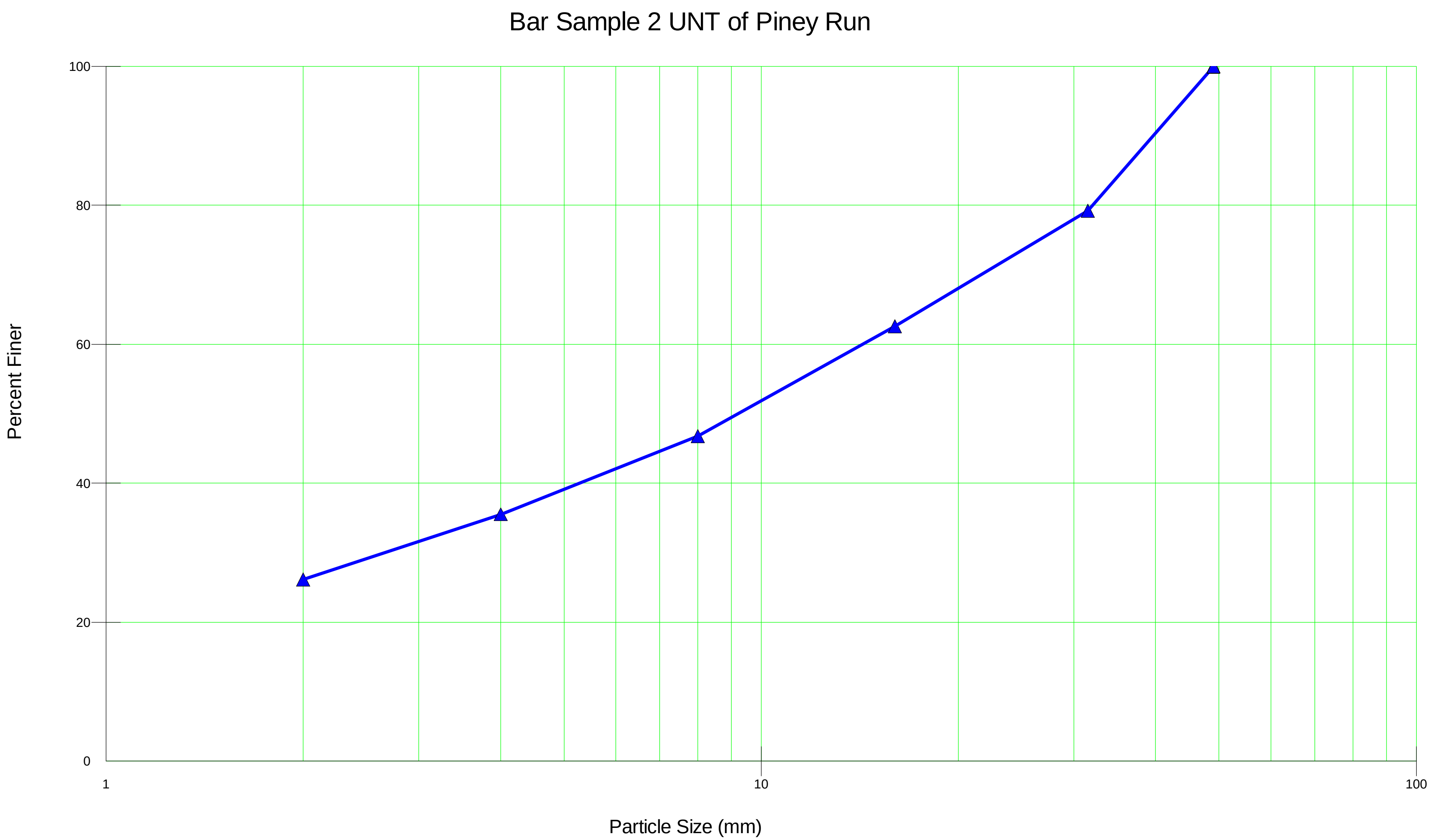
SIEVE (mm)	NET WT
31.5	5.65
16	5.325
8	5.035
4	3.595
2	2.99
PAN	8.355

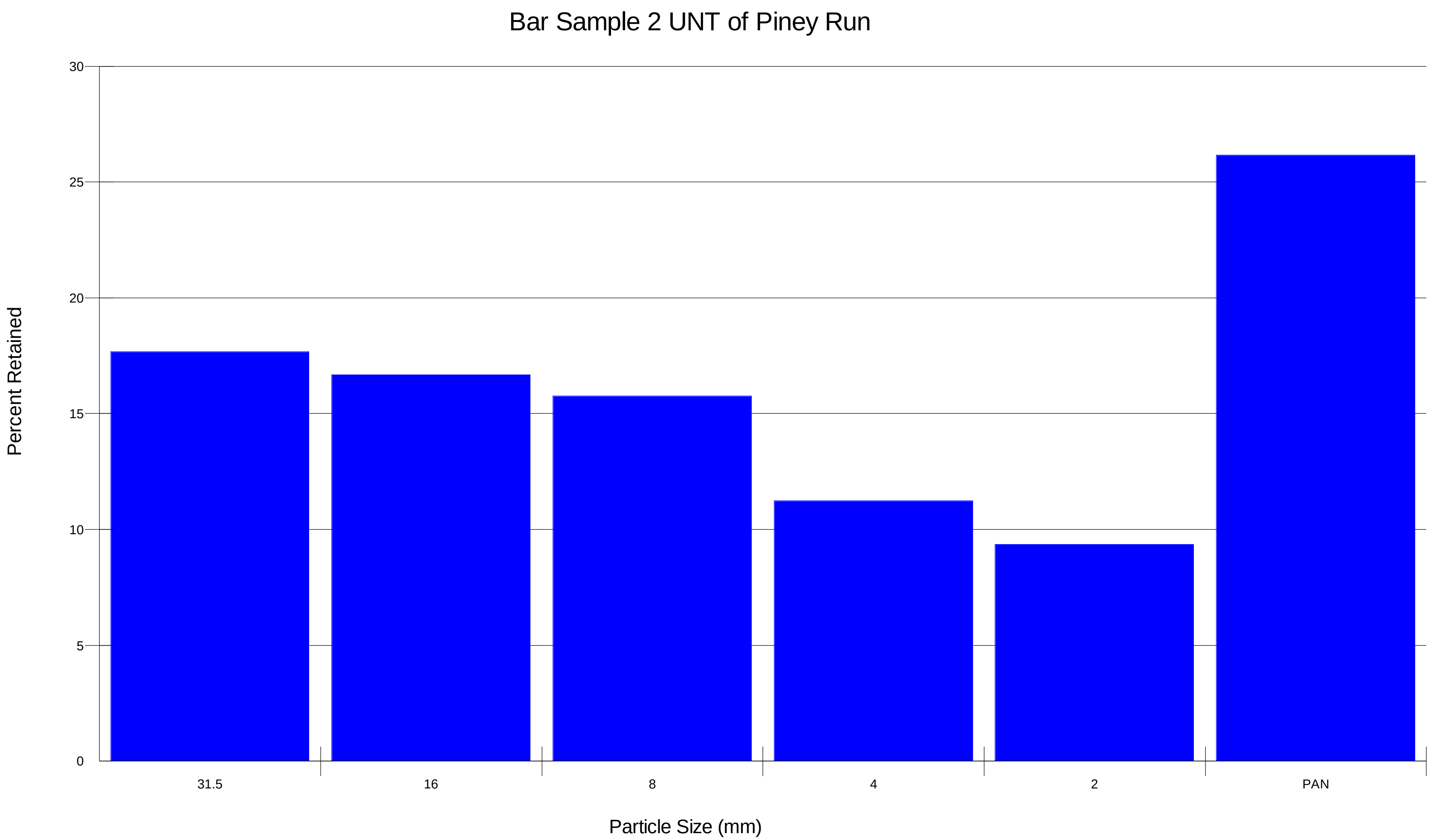
D16 (mm)	0
D35 (mm)	3.89
D50 (mm)	9.63
D84 (mm)	35.52
D95 (mm)	44.79
D100 (mm)	51
Silt/Clay (%)	0
Sand (%)	26.17
Gravel (%)	73.83
Cobble (%)	0
Boulder (%)	0
Bedrock (%)	0

Total Weight = 31.9300.

Largest Surface Particles:

	Size(mm)	Weight
Particle 1:	49	0.43
Particle 2:	51	0.55


Bar Sample 2 UNT of Piney Run
Percent Finer
0
20
40
60
80
100
1
10
100
Particle Size (mm)



Bar Sample 2 UNT of Piney Run
Percent Retained
30
25
20
15
10
5
0
31.5
16
8
4
2
PAN
Particle Size (mm)

Appendix D: Beaver Run USGS Gage Analysis Data

Excerpt from:

McCandless, T.L. and R.A. Everett. 2002. Maryland Stream Survey: Bankfull discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region. U.S. Fish and Wildlife Service, Annapolis, MD. CBFO-S02-01.

BEAVER RUN NEAR FINKSBURG, MD
USGS STATION NUMBER: 1586210

Latitude:	39^o 29' 22"	Gage Period of Record:	1982 - Present
Longitude:	76^o 54' 12"	Mean Annual Discharge (cfs):	16.60
ADC Map Coordinates:	Carroll / 1994	Rosgen Stream Type:	C4/1
	Map 26 / A7	Survey Dates	Oct. 1997
Drainage Area (sq. mi.):	14.00		Sept. 1998
Stream Order / Magnitude:	3 / 30		
Percent Imperviousness:	8.59		

Land Use (%): Residential: 19.03 Agricultural: 51.32 Forest: 25.61 Commercial: 3.69

Log-Pearson Flood Frequency Discharge (cfs): $Q_{1.005}$: 151.80 $Q_{1.5}$: 520.00 $Q_{2.0}$: 733.20
(Log-Pearson Period: 1983 - 1995)

General Study Reach Description: The downstream end of the study reach is 220 feet upstream of the gage. The study reach has pool/riffle features, a regular meander pattern controlled by bedrock with some gabion/rip-rap revetment along the road on a portion of the right bank. The reach exhibits a bi-modal distribution of gravel and bedrock with point- and side-bar depositional features, some lateral scour, and is vertically stable. The reach contains several pieces of large woody debris, one of which spans the channel, and numerous boulders. The bank vegetation is comprised of trees and sparse grass, while the floodplain vegetation is moderately dense forest of hickory, ash, tulip poplar, beech and oak, with a moderately dense understory of spice bush, witch hazel, and rhododendron.

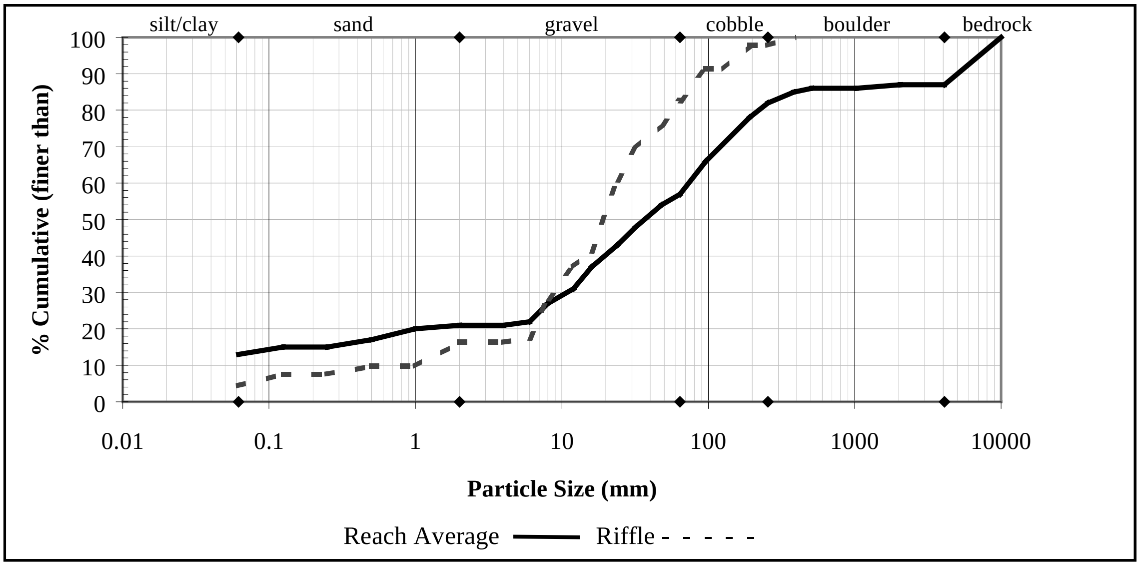
DISCHARGE BASED ON SURVEY OF GEOMORPHIC FEATURES

Bankfull Discharge (Q_{bkf} cfs):	626.90	Q_{bkf} / $Q_{2.0}$:	0.86	
Bankfull Return Interval (R.I.):	1.73	$Q_{Top\ of\ Bank}$(cfs):	n/a	R.I.: n/a
Gage Height (ft):	3.61	$Q_{Active\ Channel}$ (cfs):	n/a	R.I.: n/a
Q_{bkf} / $Q_{1.5}$:	1.21			

STUDY REACH SURVEY INFORMATION

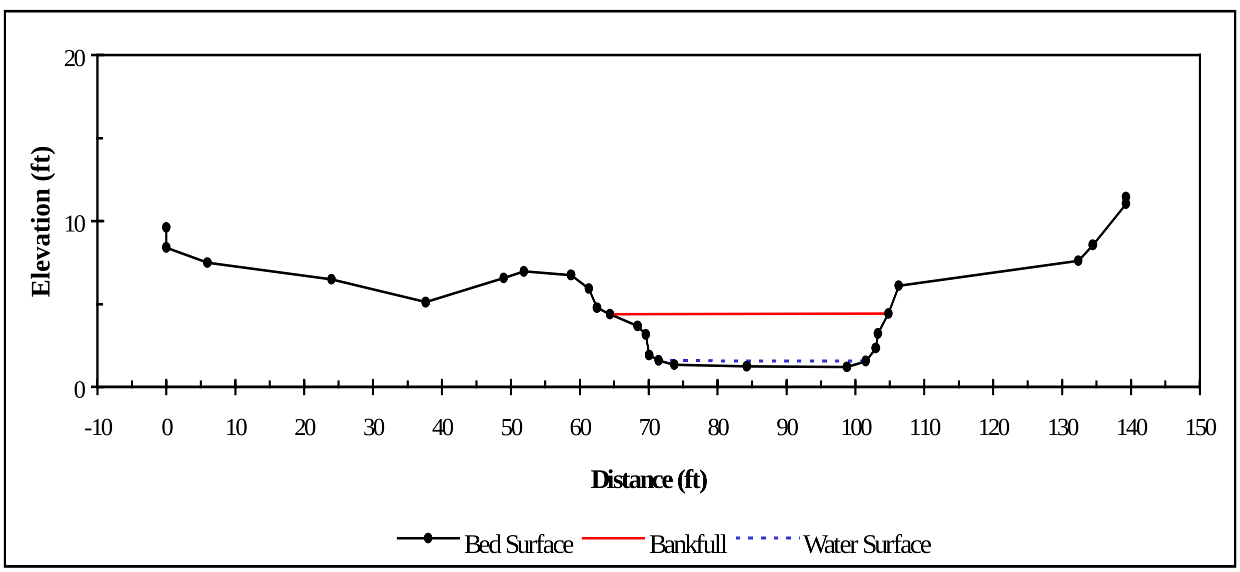
Average Water Surface Slope (ft/ft):	0.0050	Flood-prone Width (ft):	126.40
Manning's "n":	0.032	Entrenchment Ratio:	3.13
Mean Bankfull Velocity (ft/sec):	5.93	Width/Depth Ratio:	15.49
u/u*:	9.41	Channel Sinuosity:	1.06
R/D_{84}:	11.04	Beltwidth:	87
Froude Number:	0.65	Meander Width Ratio:	2.2

BEAVER RUN NEAR FINKSBURG, MD
PARTICLE SIZE DISTRIBUTION



Particle Size (mm)		
Finer Than	Reach	Riffle
D_{16}	0.35	1.94
D_{35}	14.54	10.95
D_{50}	36.63	19.16
D_{84}	335.45	68.29
D_{95}	Bedrock	161.06

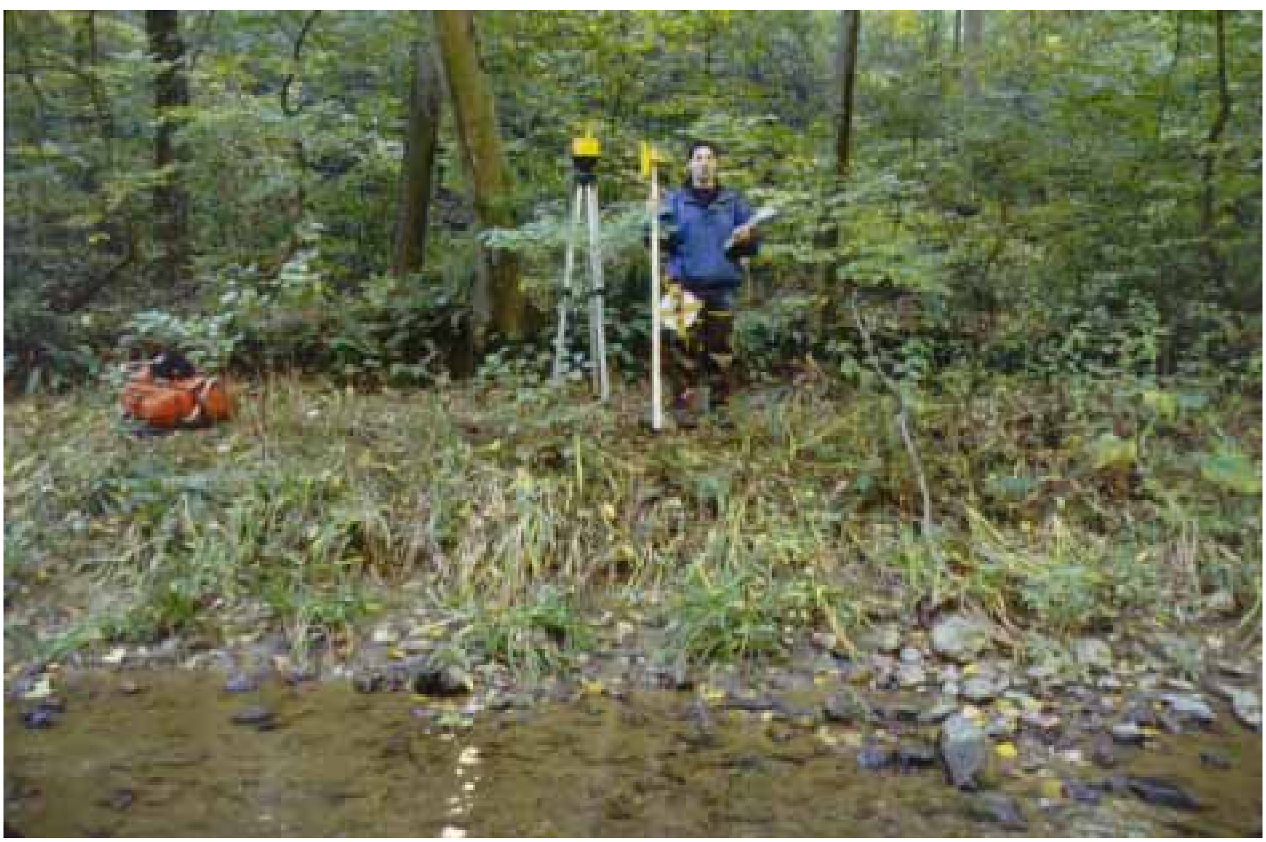
STUDY REACH CROSS SECTION



Bankfull Width (ft):	40.43	Bankfull Depth (ft):	2.61
Bankfull Cross-sectional Area (ft^2):	105.69	Maximum Bankfull Depth (ft):	3.20
Hydraulic Radius (ft):	2.47	Wetted Perimeter (ft):	42.74

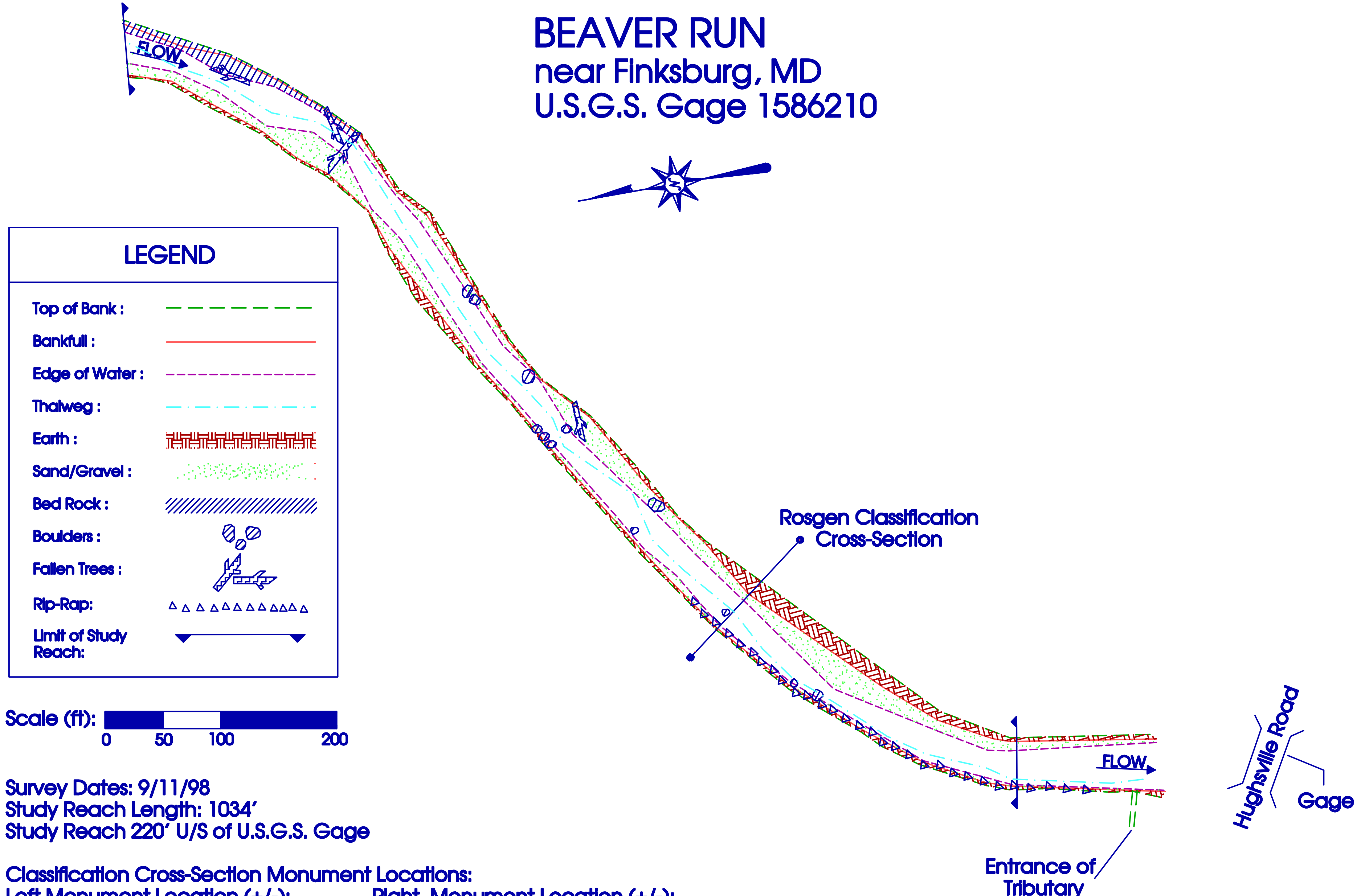
Beaver Run near Finksburg, Maryland

Upstream view of classification cross-section



Left bank of classification cross-section

BEAVER RUN
near Finksburg, MD
U.S.G.S. Gage 1586210



Survey Dates: 9/11/98
Study Reach Length: 1034'
Study Reach 220' U/S of U.S.G.S. Gage

Classification Cross-Section Monument Locations:

Left Monument Location (+/-):	Right Monument Location (+/-):
N/A	N/A
N/A	N/A

Appendix E: FLOWSED Model Computations

RIVERMORPH FLOWSED/POWERSED INPUT SUMMARY

FLOWSED/POWERSED Model Run: FLOWSED/POWERSED Run - PIney Run 11-6-19

Selected Cross Sections:

Reach 1: Stable or Reference Cross Section: 60614688 - Piney Run Reservoir, Piney
Bankfull Discharge (cfs): 364.86 - user defined
Measured Bankfull Bedload (lb/s): 0.232
Measured Bankfull Suspended Sediment (mg/l): 35.94
Use Hydraulic Geometry from the Entire Cross Section

Reach 2: Altered or Unstable Cross Section: --none selected--
Bankfull Discharge (cfs): 0 - user defined
Use Hydraulic Geometry from the Entire Cross Section

Selected Flow Duration Curve:

Gage Name: 01586210 Beaver Run, Finksburg, MD Bankfull Discharge (cfs): 620

Selected Sediment Rating Curves:

Reach 1
Dimensionless Bedload Rating Curve
Name: Pagosa Springs Reference Curve; Stability Rating: Poor
$y = 0.07176 + 1.0218 x ^ {2.3772}$

Dimensionless Suspended Sediment Rating Curve
Name: Pagosa Springs Reference Curve; Stability Rating: Poor
$y = 0.0989 + 0.9213 x ^ {3.6590}$

Dimensionless Conversion (FLOWSED)

X	Y	Q	Qbed	Qsand
0.1	0.10	36.530	0.0176	3.562
0.2	0.10	73.060	0.0218	3.646
0.3	0.11	109.590	0.0302	3.959
0.4	0.13	146.120	0.0435	4.713
0.5	0.17	182.650	0.0623	6.176
0.6	0.24	219.180	0.0870	8.662
0.7	0.35	255.710	0.1182	12.533
0.8	0.51	292.240	0.1561	18.189
0.9	0.73	328.770	0.2012	26.074
1.0	1.02	365.300	0.2537	36.666
1.1	1.40	401.830	0.3140	50.483
1.2	1.89	438.360	0.3823	68.076

FLOWSED Worksheet. The calculations of total annual sediment yield using the FLOWSED model.

Stream: **60614688 - Piney Run Reservoir**	Location: **Piney Run**	Date: **12/20/2019**
Observers: **Brandon Alderman, Dan Wagner**	Gage Station #: **1586210**	Stream Type: **C 4 / F4**	Landscape Type: **U-AL-FD**

Equation & Source	Momentary Maximum Bankfull Discharge, Q_{bkf} (cfs)	Mean Daily Bankfull Discharge, Q_{mndbkf} (cfs)	Bankfull Bedload Sediment, b_{bkf} (kg/s)	Bankfull Suspended Sediment, S_{bkf} (mg/l)	Bankfull Suspended Sand Sediment, S_{bkf} (mg/l)
1. Bedload "Poor" Pagosa: $y = 0.07176+1.0218x^{2.3772}$ 2. Suspended "Poor" Pagosa: $y = 0.0989+0.9213x^{3.6590}$	364.86	364.86	0.1052	19.63	35.94

From Localized Flow-Duration Curve						From DSRCs			From SRCs			Calculate	Calculate Annual Sediment Yield			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Percentage of Time	Mean Daily Discharge	Mid-Ordinate Percentage of Time	Time Increment (percent)	Time Increment (days)	Mid-Ordinate Stream-flow, Q	Dimension-less Streamflow	Dimension-less Bedload Discharge	Dimension-less Susp. & Susp. Sand Sed. Discharge	Daily Mean Bedload Transport Rate	Daily Mean Suspended Sediment Transport Rate	Daily Mean Suspended Sand Transport Rate	Time Adjusted Streamflow [(5)×(6)]	Bedload Sediment [(5)×(10)]	Suspended Sediment [(5)×(11)]	Susp. Sand Sediment [(5)×(12)]	TOTAL: Bedload + Suspended Sediment [(14)+(15)]
(%)	(cfs)	(%)	(%)	(days)	(cfs)	(Q/Q_{bkf})	(b_s/b_{bkf})	(S/S_{bkf})	(tons/day)	(tons/day)	(tons/day)	(cfs)	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
100	9.85															
90	189.73	95.00	10.00	36.50	99.91	0.27	0.12	0.11	1.21	0.57	1.04	3646.71	44.16	20.80	37.96	64.96
80	251.02	85.00	10.00	36.50	220.65	0.60	0.38	0.25	3.80	2.87	5.25	8053.73	138.70	104.76	191.63	243.46
70	310.13	75.00	10.00	36.50	280.92	0.77	0.62	0.45	6.22	6.74	12.35	10253.58	227.03	246.01	450.77	473.04
60	375.81	65.00	10.00	36.50	343.38	0.94	0.96	0.84	9.55	15.23	27.88	12533.37	348.58	555.89	1017.62	904.47
50	463.37	55.00	10.00	36.50	420.10	1.15	1.50	1.64	14.99	36.56	66.94	15333.65	547.13	1334.44	2443.31	1881.57
40	547.29	45.00	10.00	36.50	505.94	1.39	2.29	3.15	22.94	84.35	154.46	18466.81	837.31	3078.77	5637.79	3916.08
30	660.40	35.00	10.00	36.50	604.57	1.66	3.47	5.95	34.65	190.51	348.80	22066.81	1264.72	6953.61	12731.20	8218.33
20	839.18	25.00			750.69	2.06	5.75	13.01				0.00	0.00	0.00	0.00	0.00
10	1182.15	15.00			1011.88	2.77	11.62	38.59				0.00	0.00	0.00	0.00	0.00
5	1630.92	7.50			1408.23	3.86	25.41	129.10				0.00	0.00	0.00	0.00	0.00
4	1762.27	4.50			1698.64	4.66	39.63	256.27				0.00	0.00	0.00	0.00	0.00
3	2014.03	3.50			1890.43	5.18	51.09	378.99				0.00	0.00	0.00	0.00	0.00
2	2419.02	2.50			2219.20	6.08	74.76	681.36				0.00	0.00	0.00	0.00	0.00
1.5	2962.66	1.75			2694.09	7.38	118.50	1385.13				0.00	0.00	0.00	0.00	0.00
1	3648.60	1.25			3309.62	9.07	193.22	2940.79				0.00	0.00	0.00	0.00	0.00
0.9	3940.49	0.95			3799.12	10.41	268.17	4871.36				0.00	0.00	0.00	0.00	0.00
0.8	4232.38	0.85			4091.36	11.21	319.82	6388.69				0.00	0.00	0.00	0.00	0.00
0.7	4597.24	0.75			4420.13	12.11	384.32	8476.82				0.00	0.00	0.00	0.00	0.00
0.6	4962.10	0.65			4785.43	13.12	464.15	11334.85				0.00	0.00	0.00	0.00	0.00
0.5	5618.84	0.55			5296.85	14.52	590.84	16434.80				0.00	0.00	0.00	0.00	0.00
0.25	7479.63	0.38			6557.14	17.97	981.31	35887.28				0.00	0.00	0.00	0.00	0.00
0.1	11420.12	0.18			9461.27	25.93	2345.95	137271.51				0.00	0.00	0.00	0.00	0.00
0.05	15214.66	0.08			13333.45	36.54	5302.72	481665.94				0.00	0.00	0.00	0.00	0.00
0.01	18388.94	0.03			16822.06	46.11	9213.88	1127387.09				0.00	0.00	0.00	0.00	0.00
0.005	19264.61	0.01			18849.48	51.66	12076.01	1709627.69				0.00	0.00	0.00	0.00	0.00
0.001	19264.61	0.00			19287.84	52.86	12754.34	1859661.09				0.00	0.00	0.00	0.00	0.00
										Annual Totals:		90,354.7 (cfs) 179,215.9 (acre-ft)	3407.6 (tons/yr)	12294.3 (tons/yr)	22510.3 (tons/yr)	15701.9 (tons/yr)

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RIVERMORPH FLOWSED/POWERSED INPUT SUMMARY

FLOWSED/POWERSED Model Run: FLOWSED/POWERSED UNT of Piney Run - 11-06-2019

Selected Cross Sections:

Reach 1: Stable or Reference Cross Section: 60614688 - Piney Run Reservoir, UNT o
Bankfull Discharge (cfs): 122.49 - user defined
Measured Bankfull Bedload (lb/s): 0.232
Measured Bankfull Suspended Sediment (mg/l): 35.94
Use Hydraulic Geometry from the Entire Cross Section

Reach 2: Altered or Unstable Cross Section: --none selected--
Bankfull Discharge (cfs): 0 - user defined
Use Hydraulic Geometry from the Entire Cross Section

Selected Flow Duration Curve:

Gage Name: 01586210 Beaver Run, Finksburg, MD Bankfull Discharge (cfs): 620

Selected Sediment Rating Curves:

Reach 1
Dimensionless Bedload Rating Curve
Name: Pagosa Springs Reference Curve; Stability Rating: Poor
$y = 0.07176 + 1.0218 x ^ 2.3772$

Dimensionless Suspended Sediment Rating Curve
Name: Pagosa Springs Reference Curve; Stability Rating: Poor
$y = 0.0989 + 0.9213 x ^ 3.6590$

Dimensionless Conversion (FLOWSED)

X	Y	Q	Qbed	Qsand
0.1	0.10	11.479	0.0176	3.562
0.2	0.10	22.958	0.0218	3.646
0.3	0.11	34.437	0.0302	3.959
0.4	0.13	45.916	0.0435	4.713
0.5	0.17	57.395	0.0623	6.176
0.6	0.24	68.874	0.0870	8.662
0.7	0.35	80.353	0.1182	12.533
0.8	0.51	91.832	0.1561	18.189
0.9	0.73	103.311	0.2012	26.074
1.0	1.02	114.790	0.2537	36.666
1.1	1.40	126.269	0.3140	50.483
1.2	1.89	137.748	0.3823	68.076

FLOWSED Worksheet. The calculations of total annual sediment yield using the FLOWSED model.

Stream: **60614688 - Piney Run Reservoir** Location: **UNT of Piney Run** Date: **12/20/2019**

Observers: **Brandon Alderman/Dan Wagner** Gage Station #: **1586210** Stream Type: **F4** Landscape Type: **U-AL-FD**

Equation & Source	Momentary Maximum Bankfull Discharge, Q_{bkf} (cfs)	Mean Daily Bankfull Discharge, Q_{mndbkf} (cfs)	Bankfull Bedload Sediment, b_{bkf} (kg/s)	Bankfull Suspended Sediment, S_{bkf} (mg/l)	Bankfull Suspended Sand Sediment, S_{bkf} (mg/l)
1. Bedload "Poor" Pagosa: $y = 0.07176+1.0218x^{2.3772}$ 2. Suspended "Poor" Pagosa: $y = 0.0989+0.9213x^{3.6590}$	122.49	122.49	0.1052	19.63	35.94

From Localized Flow-Duration Curve						From DSRCs			From SRCs			Calculate	Calculate Annual Sediment Yield			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Percentage of Time	Mean Daily Discharge	Mid-Ordinate Percentage of Time	Time Increment (percent)	Time Increment (days)	Mid-Ordinate Stream-flow, Q	Dimension-less Streamflow	Dimension-less Bedload Discharge	Dimension-less Susp. & Susp. Sand Sed. Discharge	Daily Mean Bedload Transport Rate	Daily Mean Suspended Sediment Transport Rate	Daily Mean Suspended Sand Transport Rate	Time Adjusted Streamflow **[(5)×(6)]**	Bedload Sediment **[(5)×(10)]**	Suspended Sediment **[(5)×(11)]**	Susp. Sand Sediment **[(5)×(12)]**	**TOTAL:** Bedload + Suspended Sediment **[(14)+(15)]**
(%)	(cfs)	(%)	(%)	(days)	(cfs)	(Q/Q_{bkf})	(b_s/b_{bkf})	(S/S_{bkf})	(tons/day)	(tons/day)	(tons/day)	(cfs)	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
100	3.31															
90	63.70	95.00	10.00	36.50	31.39	0.26	0.11	0.11	1.21	0.18	0.32	1145.74	44.16	6.57	11.68	50.73
80	84.27	85.00	10.00	36.50	69.34	0.57	0.34	0.21	3.80	0.79	1.44	2530.91	138.70	28.84	52.56	167.54
70	104.12	75.00	10.00	36.50	88.28	0.72	0.54	0.38	6.22	1.76	3.23	3222.22	227.03	64.24	117.89	291.27
60	126.17	65.00	10.00	36.50	107.90	0.88	0.83	0.68	9.55	3.88	7.10	3938.35	348.58	141.62	259.15	490.20
50	155.56	55.00	10.00	36.50	132.00	1.08	1.29	1.31	14.99	9.17	16.78	4818.00	547.13	334.70	612.47	881.83
40	183.74	45.00	10.00	36.50	158.99	1.30	1.97	2.49	22.94	21.00	38.44	5803.14	837.31	766.50	1403.06	1603.81
30	221.71	35.00	10.00	36.50	189.98	1.55	2.97	4.69	34.65	47.22	86.45	6934.27	1264.72	1723.53	3155.43	2988.25
20	281.73	25.00			235.89	1.93	4.92	10.23				0.00	0.00	0.00	0.00	0.00
10	396.87	15.00			317.97	2.60	9.94	30.32				0.00	0.00	0.00	0.00	0.00
5	547.53	7.50			442.51	3.61	21.72	101.37				0.00	0.00	0.00	0.00	0.00
4	591.63	4.50			533.78	4.36	33.88	201.22				0.00	0.00	0.00	0.00	0.00
3	676.14	3.50			594.04	4.85	43.67	297.56				0.00	0.00	0.00	0.00	0.00
2	812.11	2.50			697.35	5.69	63.90	534.94				0.00	0.00	0.00	0.00	0.00
1.5	994.62	1.75			846.58	6.91	101.27	1087.47				0.00	0.00	0.00	0.00	0.00
1	1224.90	1.25			1040.00	8.49	165.13	2308.79				0.00	0.00	0.00	0.00	0.00
0.9	1322.89	0.95			1193.82	9.75	229.18	3824.47				0.00	0.00	0.00	0.00	0.00
0.8	1420.88	0.85			1285.64	10.50	273.30	5015.53				0.00	0.00	0.00	0.00	0.00
0.7	1543.37	0.75			1388.95	11.34	328.41	6654.84				0.00	0.00	0.00	0.00	0.00
0.6	1665.86	0.65			1503.74	12.28	396.63	8898.58				0.00	0.00	0.00	0.00	0.00
0.5	1886.35	0.55			1664.45	13.59	504.89	12902.50				0.00	0.00	0.00	0.00	0.00
0.25	2511.05	0.38			2060.48	16.82	838.56	28174.28				0.00	0.00	0.00	0.00	0.00
0.1	3833.94	0.18			2973.06	24.27	2004.70	107768.91				0.00	0.00	0.00	0.00	0.00
0.05	5107.83	0.08			4189.84	34.21	4531.35	378147.64				0.00	0.00	0.00	0.00	0.00
0.01	6173.50	0.03			5286.08	43.16	7873.55	885089.57				0.00	0.00	0.00	0.00	0.00
0.005	6467.47	0.01			5923.16	48.36	10319.30	1342190.02				0.00	0.00	0.00	0.00	0.00
0.001	6467.47	0.00			6060.91	49.48	10898.96	1459979.70				0.00	0.00	0.00	0.00	0.00
										Annual Totals:		28,392.6 (cfs) 56,316.0 (acre-ft)	3407.6 (tons/yr)	3066.0 (tons/yr)	5612.2 (tons/yr)	6473.6 (tons/yr)

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