APPENDIX D – INVESTIGATIONS AND ANALYSES REPORT

Appendix D – Investigation and Analysis Report

D.1 Watershed Data Collection

A desktop study was performed to collect watershed data pertaining to topography, land ownership, hydrologic features and floodplains, sediment terraces and erosion rates, and vegetative canopy. This data was compiled into a geospatial mapping database consisting of Geographic Information Systems (GIS) layers that stored various data attributes and visually displayed the data. This work was performed by the Water Science Institute (WSI), a firm specializing in GIS mapping of watersheds, differencing of digital elevation modeling, and focused watershed resource analyses.

The watershed data in the database was added as an attribute to all potential evaluation units (EUs) in the watershed. An EU is defined as a parcel of land that is also on a riparian corridor and within the project area defined in the Chiques Creek Watershed Plan and Programmatic Environmental Assessment (Plan-PEA). Data from the watershed layers were applied as attributes to potential EUs as relevant to the purpose and need of this Plan-PEA and to generally support the engineering and economic analyses presented in Appendices D.2, D.3, D.4, D.6, and D.7. Environmental resources in the watershed were developed in a separate desktop study, presented in Appendix D.5.

D.1.1 Topography

Topographic data for the watershed was developed from the most recent LiDAR data (3rd generation) for the region, acquired in 2019 by the U.S. Geological Survey (USGS).

D.1.2 Parcels/Evaluation Units (EUs)

Parcel data was obtained from the Lancaster County Assessor. This data included typical public information about the parcels, such as the owner, address, and size. Potential EUs were initially identified by selecting parcels within the project area and on a riparian corridor; a total of 1,762 potential EUs were identified in the project area.

D.1.3 Hydrologic Features

Hydrologic data included watershed and subwatershed boundaries and names, stream channel locations and names, and the order of each stream. The length and stream order of the stream channel contained within or adjacent to each EU were calculated and stored as attributes in the parcel data.

The floodplain extents in the watershed were mapped by WSI based on the USGS 2019 LiDAR data. The LiDAR data was used to identify relatively flat areas adjacent to the stream channel and within the stream corridor. These flat areas were considered to be representative of the floodplain extents and the approximate extents of the sediment terraces.

D.1.4 Erosion Rates

The erosion rates of stream banks throughout the watershed were calculated by comparing LiDAR digital topographic data from 2014 (2nd generation, by USGS) to the data from 2019 (3rd generation, by USGS). The two LiDAR surfaces were compared; the locations where sediment had been removed were identified and the volume of the removed sediment at each location was computed. The erosion rate was calculated by dividing the volume of sediment removed by the amount of time over which the erosion occurred.

The erosion data layer was normalized by the stream length contained within an EU and stored as an attribute of the EU. The unit of the erosion data is pounds of sediment per foot of stream length per year.

D.1.5 Sediment Terrace Volumes

Sediment terrace volume was estimated using a combination of mapped floodplain boundaries (described in Appendix D.1.3) and stream channel thalweg elevation from the USGS 2019 LiDAR. A surface was created at the elevation of the stream thalweg interpolated every 10 meters and extending to the approximate boundary of the floodplain; this surface represented the approximate bottom of the sediment terrace. The LiDAR surface from 2019 was compared to the sediment terrace base surface. The polygon layer resulting from these two surfaces provided the estimated boundaries and volume of the sediment terraces.

The sediment terrace volume within each EU was calculated and added to the EU as an attribute. The volume was also converted to a mass of sediment using a bulk density of 66.8 pounds per cubic foot based on legacy sediment samples collected within the Chiques Creek Watershed.

D.1.6 Mill Dams

The location and status (breached or active) of all known historic and non-historic mill dams were identified using several sources of information including historic atlas maps, regulatory source material, previous field investigations, and aerial imagery. Fifty-three mill dams were identified within the watershed. Of the 53 mill dams, 41 mill dams were historic mill dams first documented in atlas maps from the mid-19th century. Forty-six of the 53 mill dams in the watershed have been breached while seven remain intact and operational in 2025.

The distance from each parcel to the nearest mill dam (either breached or active) was calculated and stored as an attribute of the parcel.

D.1.7 Canopy Height and Density

Satellite raster imagery from 2014 was used to develop a polygon layer for canopy cover in the riparian zones of the watershed. The layer sorted the canopy heights into four height categories and developed boundaries for the surface area of each height category. The four height categories were as follows:

- Low: 13 to 36 feet
- Medium: 36 to 59 feet
- Tall: 59 to 82 feet
- Very Tall: 82 to 128 feet

The surface area of each canopy height category within each EU was calculated and stored as an attribute of the parcel. To effectively compare EUs, a unitless canopy factor was developed that consolidated the four canopy height areas into a single value. The canopy factor weighted the height categories using the following equation:

Canopy Factor = ((Low Canopy Area x 1.0) + (Medium Canopy Area x 1.1) + (Tall Canopy Area x 1.2) + (Very Tall Canopy Area x 1.3)) x 0.0001

The weighting factors in the above equation account for the relative heights of each category so that the canopy factor is a value representing both the height and density of the canopy cover within each EU. The canopy factor was applied to each EU as an attribute, and sorted into three categories (high, medium, and low) based on the range of canopy factors in the watershed.

D.2 Evaluation Unit (EU) Screening and Selection Process

The purpose of the screening and selection process was to use the results of the scoping meeting, watershed data, and EU-specific data from Appendix D.2 to select a portfolio of 10 EUs for site-specific data collection and analysis. The objective of the screening process was to generally identify sites that had high legacy sediment erosion rates, large terrace volumes, and otherwise diverse site characteristics to obtain a portfolio of 10 EUs that represented the diversity of erosion sites in the Chiques Creek Watershed; the evaluations performed on the portfolio of 10 EUs were ultimately used to inform the programmatic alternative of the Plan-PEA.

The screening and selection process was completed in three primary steps, described in the following sections.

D.2.1 Step 1 – Identification of 55 Potential EUs

A total of 1,762 potential EUs were identified in the project area, as presented in Appendix D.2.2. The objective of screening Step 1 was to develop several screening scenarios to select 55 EUs from the 1,762 potential EUs. Four screening scenarios were developed, each with a different methodology and approach to sort the 1,762 potential EUs and select 55 EUs.

The initial screening scenario eliminated all EUs with less than 300 feet of stream length in the EU, sorted the remaining EUs by erosion rate from highest to lowest, and identified the top 55 sites in the list. Parcels with less than 300 feet in the project area were considered unlikely to be viable legacy sediment treatment project sites. The 10 highest erosion rate values in the data set, excluding an outlier, generally range from 100 to 400 pounds/foot of stream/year, while the rest of the values generally range from 30 to 70 pounds/foot of stream/year.

The initial screening scenario served as a basis for the other three scenarios; each of the other three scenarios were compared to the initial to identify the commonly selected sites. The three additional screening scenarios were developed as summarized below:

- The highest erosion rates among sites with greater than 1,000 feet of stream length. The purpose of this selection is to evaluate how many high-erosion sites are screened out by selecting parcels with more stream length. Increasing the minimum stream length removed 21 sites from the initial screening scenario.
- Sediment volume in the parcel was weighted at 70 percent and the erosion rate at 30 percent, and the highest-ranking sites based on the composite weighting were selected. Sites with the highest sediment volumes are favored, which are typically larger sites with more stream length.
- The highest erosion rates among sites with greater than 300 feet of stream length and located on streams of orders 1 and 2 were selected. The purpose of this screening is to select the sites in the headwaters with the highest erosion rates.

The results from each of the four screening scenarios were compared to identify commonly selected sites among the four scenarios, which were considered in Step 2 of the screening process.

D.2.2 Step 2 – Identification of 35 Potential EUs

While there were no sites common to all four screening scenarios evaluated in Step 1, there were 23 EUs common to three scenarios out of the four. The 23 EUs are generally characterized as follows:

- Most of the sites are located on Little Chiques Creek.
- The 23 EUs have erosion rates between 31 and 221 pounds/foot of stream/year, which is representative of the highest erosion rates in the watershed.
- Each of the 23 EUs have greater than 1,000 feet of stream length contained within the parcel.
- Six of the 23 EUs are located adjacent to breached mill dams.
- The 23 EUs have diverse canopy cover levels in the riparian zone.
- Two of the 23 sites are located on streams of orders 1 and 2.

All 23 EUs were included in the 35 EUs selected for further evaluation. Twelve additional EUs were manually selected to increase the diversity in site conditions represented among the 35 EUs. Manual selection of the 12 additional EUs was based on the following screening scenarios:

- An additional screening scenario was developed to select sites in the headwaters with high sediment volumes. EUs in streams of orders 1 and 2 were screened by weighting sediment volume in the parcel at 70 percent and erosion rate at 30 percent, and the 55 highest-ranking EUs were selected. Ten EUs among the highest-ranking EUs in this scenario were selected to be included in the 35 sites.
- Two additional sites were selected from the screening scenario in Step 1 that selected the highest-ranking parcels by weighting sediment volume at 70 percent and erosion rate at 30 percent; these two EUs had different site conditions than those included in the 23 EUs.

Together, the 12 manually selected sites have diverse canopy covers, incorporate more sites located on streams of orders 1 and 2, emphasize sites with relatively high sediment volumes, and four sites are located adjacent to breached mill dams. A summary of the screening criteria met by each of the 35 sites is shown in Table D.2.1 below.

TABLE D.2.1
SUMMARY OF SCREENING CRITERIA MET BY THE 35 SELECTED SITES

Site ID#	Part of the 23 common sites	Screening Criteria: Top 1/3 of sites in the watershed by erosion rate	Top 1/3 of sites in the watershed by sediment volume	Streams of Orders 1 or 2	High Canopy	Medium Canopy	Low Canopy	Adjacent to mill dam	Same owner on both sides of stream	Greater than 1000 feet of stream length in parcel
1	YES	X	X		X				X	X
2	YES	X	X			X			X	X
3	YES	X	X				X			X
4	YES	X	X		X				X	X
5	YES	X	X		X					X
6	YES	X	X		X				X	X
7	YES	X		X			X		X	X
8	NO	X	X	X	X					X
9	NO	X	X	X		X			X	X
10	YES	X	X			X				X
11	NO	X	X			X		X	X	X
12	YES	X	X		X				X	X
13	NO	X	X	X			X		X	X
14	YES	X	X		X					X
15	YES	X	X				X	X	X	X
16	YES	X	X				X	X	X	X
17	NO	X	X	X		X			X	X
18	YES	X		X			X			X
19	NO	X	X	X		X				X
20	NO	X	X		X					X
21	YES	X	X		X				X	X
22	YES	X	X			X			X	X
23	YES	X	X			X			X	X
24	NO	X	X	X	X			X	X	X
25	YES	X	X			X		X		X
26	YES	X	X				X			X
27	YES	X	X			X		X	X	X
28	NO	X	X	X	X			X	X	X
29	YES	X	X				X	X	X	X
30	YES	X	X				X		X	X
31	NO	X	X	X			X		X	X
32	YES	X	X			X				X
33	YES	X	X			X		X		X
34	NO	X	X	X		X				X
35	NO	X	X	X			X		X	X
# Sites that Meet Criteria		**35**	**33**	**12**	**11**	**13**	**11**	**9**	**22**	**35**

Note: An "X" in the above cells indicates that the screening criteria is met by the site represented by a row.

D.2.3 Step 3 – Selection of 10 EUs

Ten EUs were selected from the 35 sites in Step 2 by voluntary landowner interest and participation in the on-site data collection phase of the project. The property owners of the 35 sites identified in Step 2 were contacted (by a phone call to the number in public records and a mailed letter to the site address) to gauge landowner interest to participate in the project by allowing minimally invasive data collection on their property. Of the 35 property owners contacted, 10 property owners agreed to voluntarily participate. Therefore, those 10 EUs were selected to be included in the final portfolio. Table D.2.2 below provides the results of the landowner outreach effort.

TABLE D.2.2
LANDOWNER OUTREACH RESULTS

Site ID#	Landowner Response	Site ID#	Landowner Response	Site ID#	Landowner Response	Site ID#	Landowner Response
1	Yes	11	Yes	21	No Response	31	Declined
2	Declined	12	No Response	22	Maybe	32	Yes
3	No Response	13	No Response	23	No Response	33	Yes
4	Yes	14	No Response	24	Yes	34	No Response
5	No Response	15	Declined	25	Declined	35	Declined
6	Maybe	16	Declined	26	Declined		
7	No Response	17	No Response	27	Declined		
8	No Response	18	No Response	28	Yes		
9	Yes	19	Declined	29	Yes		
10	No Response	20	No Response	30	Yes		

The final portfolio of 10 EUs is maintained in the project's administrative file.

D.3 Evaluation Unit (EU) Data Collection

D.3.1 Site Visits

Site visits to the 10 EUs were performed from January 9 to 13, 2023. A Data Gathering Field Plan (RJH, 2023) was prepared prior to site visits to document the means, methods, and objectives of data gathering and identify all applicable safety and biohazard protocols. The general purpose of the site visits was to perform minimally invasive data collection to support the engineering and environmental evaluations in this Plan-PEA. Primary objectives of the EU visits are listed below:

- Verify legacy sediment terrace extents from the desktop study in Appendix D.2.
- Collect qualitative information to support a National Environmental Policy Act (NEPA) assessment. This information included wetland presence/absence surveys,

vegetation community characterization (wetlands, riparian zones, uplands), wildlife habitat identification, and presence of non-native, invasive species.

- Approximate location and extent of wetlands not mapped by the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI).
- Conduct a legacy sediment survey and sample legacy sediments at each EU to support evaluation of the depth and quantity of legacy sediments, and to collect samples for laboratory testing. Identify the approximate depths of both submerged and aerated sediment.
- Identify possible areas where legacy sediment can be relocated to if removal of legacy sediment is viable.
- Identify any cultural resource concerns or historical features that could be impacted by a land treatment project.
- Assess EU access constraints or other physical constraints that could impact construction at the EU.

The data collected during the site visits is summarized in the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.3.2 Subsurface Investigation

Samples of legacy sediment were obtained from each EU by boring and extraction with a hand auger. The primary purpose of the boreholes was to support evaluation of the depth, quantity, and characteristics of legacy sediment and to collect samples of legacy sediment for chemical laboratory testing. Boreholes were advanced until the extracted material was consistent with stream bed material and the full sediment terrace was profiled. The terminal depth of the boring varied by site and location. An average of about four borings were performed on each EU depending primarily on the size of the legacy sediment terrace and if the landowner had access to both sides of the stream. A representative soil sample from a single boring at each EU was placed in a labeled and sealed plastic bag for laboratory testing; more information is in Appendix D.3.3.

D.3.3 Sediment Characteristics and Testing

The legacy sediment samples obtained from the 10 EUs generally consisted of lean clay with sand or silty clay with sand and occasionally silty sand. Three representative sediment samples were tested for percent fines and Atterberg Limits. The lean clay with sand classified as a CL and had 73 precent fines (passing a No. 200 sieve), a liquid limit of 28, and a plasticity index of 8. The silty clay with sand classified as a CL-ML and had 78 percent fines, a liquid limit of 26, and a plasticity index of 6. The silty sand had 47 percent fines, a liquid limit of 21, and a plasticity index of 3 and classified as SM.

A representative sample from each EU was tested for heavy metals, comprehensive chemicals, petroleum hydrocarbons, pesticides, and per-and polyfluoroalkyl substances (PFAS). The following key results were concluded from the laboratory testing:

- The total nitrogen concentration of the samples ranged from 210 to 1220 milligrams per kilogram (mg/kg), with an average of 548 mg/kg.
- The total phosphorous concentration of the samples ranged from 0 to 391 mg/kg, with an average of 148 mg/kg.
- The expected background nutrient levels for stream bank sediments in Pennsylvania are 1,140 mg/kg and 525 mg/kg for nitrogen and phosphorous, respectively. Nutrient concentrations in the sample were generally at or lower than expected background levels.
- Pesticides, PFAS, and petroleum hydrocarbons were not present in the samples.
- Heavy metal concentrations were within expected ranges and are not concerning to human health.

The soils in the legacy sediment terraces of the 10 EUs are generally suitable for use as clean fill either on- or off-site. Test data specific to each EU and a summary of all sediment tests are presented in the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.4 Hydrology and Hydrologic Modeling

A rainfall-runoff hydrologic model was developed for the Chiques Creek Watershed to estimate the in-stream flow rates throughout the watershed during 24-hour storm events of various recurrence intervals from 1 to 500 years. The purpose of the hydrologic model was to inform the conceptual design of land treatment projects at the 10 EUs.

Hydrologic analysis and modeling of the Chiques Creek Watershed was performed based on the approach and methodology provided in the Natural Resources Conservation Service (NRCS) National Engineering Handbook (NEH) Part 630 Chapters 4, 9, and 15. More information on the development of the hydrologic model in general accordance with the NRCS hydrology method is provided in the following sections.

The following watershed data was used for the hydrologic analysis and modeling of the Chiques Creek Watershed:

- ***Topographic Data*** – Topographic data for the watershed was developed from the most recent LiDAR data (3rd generation) for the region, acquired in 2019 by the USGS.

- ***Land Cover Data*** – National Land Cover Database (NLCD) Multi-Resolution Land Characteristics (MRLC) consortium from 2019 was used to develop a map of land cover types.
- ***Soils Data*** – Soils data was downloaded as a shapefile from the NRCS Web Soil Survey (WSS).
- ***Precipitation Data*** – Precipitation depths were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Point Precipitation Frequency Estimate web tool.

D.4.1 HEC-HMS Model Setup

A watershed model was developed in Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS) Version 4.10. The 2019 LiDAR terrain data was imported into the basin model for the extent of the Chiques Creek Watershed. The basin and subbasins were delineated using GIS tools in HEC-HMS and were edited and verified using aerial imagery. The watershed shapefile of the EUs was imported into the model, and the GIS tools were used to split the subbasins at the downstream-most point of the treatment sites to provide nodes for flow data extraction at each EU. The watershed was divided into a total of 48 subbasins and the average area of a subbasin is about 2.5 square miles. Reaches with one or more inflow and only one outflow were included to model the main river channels.

Runoff losses and hydrograph transformation were calculated for each subbasin in the model using the Soil Conservation Service (SCS) method in the HEC-HMS software. The SCS method is commonly used to develop a hydrologic model that estimates runoff losses and transformation in accordance with NRCS NEH hydrology.

D.4.1.1 Precipitation

Precipitation depths were obtained from the NOAA Atlas 14 Point Precipitation Frequency Estimate online mapping tool. This tool is widely used to estimate the precipitation depths associated with various storm durations and recurrence intervals. A data point at the centroid of the Chiques Creek Watershed was selected and 24-hour-duration 1-, 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval rainfall depths were identified. Point precipitation frequency data for the watershed are summarized in Table D.4.1.

TABLE D.4.1
24-HOUR DURATION PRECIPITATION FREQUENCY DATA

Recurrence Interval (years)	Precipitation Depth (inches)
1	2.49
2	3.01
5	3.84
10	4.56
25	5.64
50	6.58
100	7.63
200	8.82
500	10.60

The rainfall depths in Table D.4.1 and the NOAA Type C Rainfall Distribution from NEH Part 650 Chapter 2 were used to develop rainfall distributions for each recurrence interval precipitation event. These rainfall distributions were added to the model as precipitation gages and the precipitation gages were assigned to each subbasin. Precipitation data and distributions are provided in the Hydrology Technical Memorandum, which is an Appendix to the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.4.1.2 Runoff Loss Method

The SCS Loss Method was selected in the HEC-HMS model to estimate the incremental precipitation losses based on the land cover properties of each subbasin. Three input parameters are required as runoff loss inputs in the model: curve number, initial abstraction, and percent imperviousness for each subbasin.

NEH Part 630 Chapter 9 provides curve numbers based on land cover type and the Hydrologic Soil Group. The NLCD MRLC was used to develop a map of land cover types in the watershed. Soils data for the watershed was downloaded as a shapefile from the NRCS WSS. A “union” was performed in GIS to produce a composite land cover and soil data set. This composite data set was clipped to each subbasin, processed to obtain a curve number for each distinct map unit in the data set, and a composite curve number for each subbasin was calculated based on the weighted average (by area) curve number of all map units in the subbasin. The curve number for each subbasin was included as a runoff loss input parameter in the model.

Initial abstraction was also calculated for each subbasin and included as a runoff loss input parameter in the model. Initial abstraction is a parameter based on curve number that defines the precipitation amount in inches that falls and is stored in the land surface before surface runoff flow initiates in the model. NEH Part 630 Chapter 15 provides equations to estimate the initial abstraction, which is generally calculated as 0.2 times the total potential retention, a parameter also based on curve number.

Percent imperviousness was entered into the model as a zero value for each subbasin because imperviousness is accounted for in the curve numbers provided in NEH Part 630 Chapter 9.

Runoff loss parameters for each subbasin are provided in the Hydrology Technical Memorandum, which is an appendix to the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.4.1.3 Hydrograph Transformation

The SCS Unit Hydrograph method was selected in the HEC-HMS model to empirically transform the precipitation excess of each subbasin into point runoff. This method is a parametric unit hydrograph model that implements a dimensionless unit hydrograph with a single peak. The time to the hydrograph peak is modeled in HEC-HMS based on two input parameters: the subbasin lag time and the computational time step.

The subbasin lag time is a parameter estimated based on the curve number, longest flow path, and average watershed land slope of each subbasin. The curve number was estimated as described above, and the longest flow path and average watershed land slope are subbasin properties that were calculated by HEC-HMS using GIS tools included in the Version 4.10 software. The lag time for each subbasin was calculated using the lag time equation in NEH Part 630 Chapter 15 and input into the model for each subbasin.

The computational time step selected for the model is one minute, which is sufficiently defined to produce an adequate number of ordinates for the subbasin hydrographs in the watershed model.

Hydrograph transformation parameters for each subbasin are provided in the Hydrology Technical Memorandum, which is an appendix to the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.4.1.4 Channel Flow

Channel flow, also referred to as reach routing, was estimated using the Muskingum-Cunge method in the HEC-HMS software. This method uses continuity and momentum equations to compute a downstream hydrograph given an upstream hydrograph and the following input parameters describing the channel properties: length, slope, Manning's "n" values in the channel and left and right overbanks, and an eight-point channel cross-section geometry. Higher-order streams are included as reaches in the model to route hydrographs downstream and provide nodes for data extraction in reaches and at reach junctions.

The eight-point channel cross-sections were developed from the 2019 USGS 3rd Generation LiDAR data at representative locations for each reach segment. Reach channel cross-sections and parameters are provided in the Hydrology Technical Memorandum, which is an appendix to the *Engineering Inventory and Evaluation Report* (RJH, 2025).

D.4.2 Results

Peak flow rates and flow hydrographs were extracted from corresponding model elements at each treatment site. The peak flow results are summarized for each EU in Table D.4.2 below.

TABLE D.4.2
PEAK FLOW RESULTS

EU Number	Stream Order	Peak Flow Rate by Storm Recurrence Interval in Years (cubic feet per second)								
		1	2	5	10	25	50	100	200	500
1	4	1,238	2,132	3,885	5,640	8,546	11,253	14,413	18,114	23,801
2	4	1,238	2,132	3,885	5,640	8,546	11,253	14,413	18,114	23,801
3	3	170	283	501	716	1,066	1,391	1,768	2,208	2,882
4	5	1,525	2,650	4,934	7,288	11,245	14,958	19,306	24,413	32,286
5	3	441	716	1,228	1,721	2,514	3,240	4,076	5,044	6,517
6	2	149	251	445	634	940	1,221	1,547	1,925	2,501
7	2	55	94	167	237	349	451	569	705	910
8	3	338	543	921	1,284	1,865	2,396	3,006	3,712	4,784
9	4	761	1,324	2,403	3,464	5,199	6,804	8,667	10,841	14,168
10	2	153	258	455	646	953	1,234	1,557	1,931	2,499

The peak flow results were checked for reasonableness against peak flows from USGS StreamStats regression statistics for each treatment site. The comparison showed that the modeled peak flow rates tended to be larger than the USGS StreamStats peak flow rates by an average of about 20 percent, which is considered conservative and appropriate for this level of study.

D.5 Environmental Resources

Desktop analyses and field surveys were conducted to evaluate environmental resources for each EU. A summary of the methodologies and findings are presented in the sections below.

D.5.1 Desktop Analysis and Field Survey Methodology

The investigation to support NEPA documentation included qualitative desktop reviews and field surveys of the existing natural resources, and the ecological settings of the project areas so that the potential for impacts to these resources can be assessed. These reviews and surveys included the following:

- Identification of areas of legacy sediment to be treated, including determining the approximate depths of both submerged and aerated sediment.
- Desktop wetland identification and field confirmation.
- Desktop wildlife habitat identification and field habitat surveys.
- Rare, threatened, and endangered (RTE) species information.
- Vegetation community descriptions including information on invasive plant species.

These reviews and field surveys were conducted to include an approximately 1,000-foot examination corridor along each EU's stream reach. The sections below describe in more detail the methods used to perform the reviews and surveys, as well as the findings for each environmental resource.

D.5.2 Soils

LiDAR data was used to approximate the area of legacy sediment prior to the field visit. The primary focus of the field investigation was to obtain the thickness of the legacy sediment at various locations across the valley and along the channel to support computation of the volume of legacy sediment on each parcel.

The sediment depth was estimated using the methods outlined in NEH Section 3 ("Sedimentation"), Chapter 7 ("Field Investigation and Survey") by pushing a rod through the legacy sediment to identify the more resistant original bottom stream material. The location and number of push rod tests at each of the field sites was determined in the field since it is dependent upon a visual assessment of the local topography, floodplain width, and degree of stream/floodplain connectivity. The waterline was delineated to locate the approximate division of submerged versus aerated legacy sediment. It was understood that the groundwater table varies throughout the year and that the groundwater table at the time of sampling is only to be used as an approximation. The average sediment depths encountered at each EU are presented below in Table D.5.1.

TABLE D.5.1
SOIL CHARACTERISTICS

EU (Number)	Average Eroded Bank Height (feet)	Average Sediment Depth (feet)	Approximate Legacy Sediment Volume (cubic yards)
1	5.0	4.9	63,000
2	6.0	5.5	65,000
3	4.0	4.6	40,000
4	6.0	5.7	43,000
5	4.0	3.6	27,000
6	2.0	2.2	19,000
7	3.0	2.3	17,000
8	5.0 (main reach), 2.0 (tributary)	2.6	23,000
9	7.0 (main reach), 3.0 (tributary)	4.2	32,000
10	3.0	1.8	13,000

D.5.3 Vegetation

A description of vegetation communities was performed concurrently with the field surveys as this information is inherent in wetland and wildlife habitat descriptions. Many sites contained significant populations of invasive species, which are further discussed in Section D.5.6. Vegetation within riparian areas was also limited at many sites due to agricultural encroachments and maintained lawn up to the stream banks. In areas with more significant riparian vegetation, the species encountered were common to the area, including poison ivy, white ash, spicebush, sycamore, common cattail, chestnut oak, white oak, red maple, and silver maple.

D.5.4 Federally Listed Species

A preliminary assessment for potential RTE species at each site was conducted first using the Pennsylvania Natural Diversity Index (PNDI) database through the PA Conservation Explorer system and the USFWS Information Planning and Consultation database. Additionally, the wildlife habitat survey examined the sites for the potential to provide suitable habitat for these species. Any observations of RTE species or their signs were documented.

The PNDI report conducted during the preliminary assessment revealed that RTE species may be present at EU 6. RTE species were not identified at any other EUs during the desktop analysis or field surveys. However, field surveys did document the presence of bald eagles at several sites.

D.5.5 Rare Plants

A preliminary assessment for potential rare plant species at each site was conducted first using the PNDI database through the PA Conservation Explorer system. Plant species encountered on-site were then documented during the field surveys. Rare plants were not identified during the desktop analysis or field surveys at the 10 EUs.

D.5.6 Invasive Species

Field surveys paid particular attention to the presence of invasive plant species since project activities often produce conditions that promote the spread of invasive species. A summary of the invasive species encountered at each EU are presented below in Table D.5.2.

TABLE D.5.2
INVASIVE SPECIES

EU (Number)	Invasive Species Present
1	Garlic mustard, multiflora rose, and reed canary grass
2	Garlic mustard, multiflora rose, bamboo, and reed canary grass
3	Poison hemlock, reed canary grass, multiflora rose, and common cocklebur
4	Garlic mustard
5	Poison hemlock and multiflora rose
6	Reed canary grass and multiflora rose
7	Reed canary grass
8	Multiflora rose and reed canary grass
9	Poison hemlock, multiflora rose, reed canary grass, Japanese honeysuckle, and common chickweed.
10	Multiflora rose, reed canary grass, and amur honeysuckle

D.5.7 Water Resources

A preliminary assessment for potential wetland areas at each site was conducted first with a desktop delineation using the USFWS' online NWI Mapper and the Pennsylvania Department of Environmental Protection (PADEP) eMap GIS database. Because these information sources are broad-scale and typically used for preliminary screening purposes, each site was confirmed in the field by a Professional Wetland Scientist to either confirm or disprove the presence of wetlands. Any additional wetlands encountered during the site visits were described and visually estimated as to their extent. Wetlands observed in the field were described as to their Cowardin classification (e.g., Palustrine Forested Wetland [PFO], Palustrine Scrub-Shrub Wetland [PSS], Palustrine Emergent Wetland [PEM]) and broadly described in terms of their vegetation community and landscape position. A summary of the wetlands identified during the field surveys are presented below.

- EU 1: Two areas of PEM1C wetlands (0.47 acres [ac] and 1.36 ac), one area of PEM1/PFO1A wetlands (3.14 ac), and one area of PEM wetlands (0.33 ac) were identified at this site. Field assessments identified these wetlands as low quality.
- EU 2: Wetlands are located along both sides of Little Chiques Creek at this site. Approximately 1.39 ac of PEM/PFO field-assessed wetlands are located along the right bank, and approximately 2.62 ac of PEM field-assessed wetlands are located along the left bank. Field assessments identified these wetlands as low-quality due to the presence of invasive species.
- EU 3: Three areas of emergent wetlands (PEM) with areas of 0.95 ac, 0.82 ac, and 2.1 ac were identified during field assessments at this site. Field assessments identified these wetlands as low quality due to the presence of invasive species.
- EU 4: Approximately 4.0 ac of PFO1A wetlands are located along the left bank of the stream. Field assessments identified these wetlands as relatively low quality due to the presence of invasive species.
- EU 5: Four areas of emergent wetlands (0.27 ac, 0.61 ac, 0.62 ac, and 1.82 ac) were identified during field assessments at this site. These wetlands are located adjacent to the stream. Field assessments identified these wetlands as low quality due to the presence of invasive species (primarily reed canary grass).
- EU 6: Two areas of PEM wetlands (0.23 ac and 0.24 ac) were identified during site field assessments. One area of PEM/PFO wetlands (0.48 ac) was also identified on-site. The wetlands at this site were identified as being in relatively good condition.
- EU 7: Two areas of PEM wetlands (1.6ac and 1.9 ac) were identified during site field assessments. Two areas of PFO wetlands (0.92 ac and 4.5 ac) were also identified on-site. The emergent wetlands at this site were identified as being of relatively low quality due to being dominated by invasive species (i.e., reed canary grass). The PFO wetlands contain an assemblage of native species and significantly fewer invasive species.
- EU 8: Three areas of emergent wetlands (0.47 ac, 0.81 ac, and 0.03 ac) were identified during field assessments at this site. Field assessments identified these wetlands as low quality due to the presence of invasive species (primarily reed canary grass and multiflora rose).
- EU 9: An approximately 0.5 ac PFO wetlands was identified during the site assessment. This wetland is a low-lying area of mature trees and maintained lawn that holds standing water. Although this wetland is not dominated by invasive species, there is little structural heterogeneity, being composed of lawn and trees.
- EU 10: Two areas of PEM wetlands were identified during the site assessment (0.34 ac and 2.9 ac). The larger emergent wetland is dominated by a near

monotypic population of reed canary grass and it is hydrologically connected to the stream and seeps from the adjacent hillside, resulting in pockets of standing water. The wetlands at this site were identified as being low quality due to the presence of invasive species.

D.5.8 Wildlife

A preliminary assessment for wildlife habitat at each site was conducted first using the PADEP eMap GIS database. The wildlife habitat at each site was then described in the field for major taxonomic groups (birds, mammals, reptiles, amphibians, terrestrial invertebrates, and aquatic invertebrates). Wildlife species observed and wildlife signs (calls, scat, tracks, etc.) were also documented.

Wildlife documented at the sites were primarily birds and mammals commonly encountered in the region, such as white-tailed deer, blue jays, red-tailed hawks, American crows, house sparrows, mourning doves, and downy woodpeckers. Bald eagles were also documented at several sites. Wildlife habitats assessed at the 10 EUs were generally of low to medium quality due to the presence of invasive species. However, EU 6 was described as having relatively good habitat quality. After conducting the field surveys, Wildlife Habitat Evaluation Guides (WHEG) were filled out for each site. The WHEG scores range from 0 (low quality) to 7 (high quality). A summary of the WHEG scores for each EU is presented below in Table D.5.3.

TABLE D.5.3
WILDLIFE HABITAT EVALUATION GUIDE SCORES

EU (Number)	WHEG Score
1	1.4
2	1.8
3	1.0
4	3.0
5	1.0
6	4.9
7	3.2
8	1.2
9	1.7
10	1.6

D.6 Evaluation of Alternatives

D.6.1 Treatments Considered for Alternative 1

Based on the GIS data and site inventory and evaluation, six legacy sediment treatment design options were considered for the 10 EUs:

- Do nothing.
- Stabilize the legacy sediment in place.
- Reforest/install riparian buffers.
- Legacy sediment removal and site restoration.
- Mill dam removal (for EUs with historic mill dams).
- Combination of the above.

The site-specific conditions at each EU provided the basis for selection of one or more design option(s) to include in the conceptual treatment project design for an EU. Generally, the driving site-specific considerations were the location and extent of stream bank erosion and volume of legacy sediment at the EU. The primary considerations for each treatment are provided in the following sections.

D.6.1.1 Do Nothing

Doing nothing is an appropriate treatment for EUs where the stream and its riparian corridor are in healthy condition and the stream banks are stable and non-eroding. In these cases, implementing another treatment is not needed because stream bank erosion is non-existent or minimal, indicating that these EUs are not contributing significant amounts of legacy sediment to the Chiques Creek Watershed's waterways. In addition to being unnecessary, trying to implement another treatment at these EUs can negatively impact the existing habitats and biodiversity because of human interference, especially for EUs where accessing the stream corridor would require impacting healthy ecosystems.

However, if an EU's stream banks are actively eroding, they are expected to continue eroding unless another treatment is implemented. Doing nothing is not a reasonable option at these EUs because the causes of any degradation, such as sediment accumulation, land use practices, or inadequate riparian buffers, would remain. Based on erosion rate data provided by WSI for the parcels containing stream segments in Chiques Creek Watershed, doing nothing will lead to a maximum erosion rate of 1.0 cubic yards of sediment per foot of stream bank each year for highly degraded or altered streams in the Chiques Creek Watershed. This erosion rate varies throughout the watershed and depends on the specific EU location.

For doing nothing to be a viable treatment, the following parameters were considered at each EU:

- Overall healthy stream system.
- Minimal legacy sediment accumulation.
- Good existing wetland and riparian buffer quality.
- Potential presence of RTE species that could potentially prevent implementing another treatment alternative.
- Existing restoration projects that are in good condition and effectively mitigating sedimentation.
- Stream banks are difficult to access and could potentially cause construction access issues.

If do nothing is chosen as the appropriate treatment option, the project will not be enrolled within the program. Preventative conservation could be employed at these sites and in adjacent upland or agricultural areas to reduce the likelihood of stream degradation in the future; however, this type of project is better suited for funding by other programs, such as the Environmental Quality Incentives Program (EQIP) and not a watershed plan under PL 83-566.

D.6.1.2 Stabilize the Legacy Sediment in Place

Stream bank stabilization aims to prevent stream bank erosion by stabilizing existing legacy sediment in place. Stream bank stabilization can involve a range of bioengineering and structural methods such as planting vegetation, installing rock structures, armoring slopes, and modifying the stream channel. Stream bank stabilization techniques can help reduce sedimentation from stream bank erosion and thereby improve water quality, enhance fish and wildlife habitat, and improve riparian continuity.

Depending on the stream bank stabilization approach and materials used, the project cost can vary greatly and the stabilization may require regular maintenance throughout its lifespan to remain effective. The stabilization design may require significant modification of the stream bank and channel, which can cause ecological disturbance such as the loss of natural habitats and vegetation, although such disturbances are usually temporary. Structural stream bank stabilization practices with limited or no functional vegetation, such as hard armoring stream banks, can potentially degrade the quality of the aquatic habitat and contribute to erosion in other areas of the stream. If stream bank erosion is a watershed-wide issue, as it is in the Chiques Creek Watershed, stream bank stabilization is unlikely to have a significant impact on reducing overall sedimentation in the watershed because it is not addressing the underlying cause of the erosion.

Depending on the methodologies selected, regulatory compliance requirements can also add to the cost and complexity of stream bank stabilization projects.

For stabilizing the legacy sediment in place to be a viable treatment alternative, the following parameters were considered at each EU:

- Existing EU conditions are amenable to stream bank stabilization alternatives.
- Legacy sediment removal and floodplain creation is not practical because of existing EU conditions and/or design constraints, such as limited space along the riparian corridor.
- Riparian corridor is amenable to vegetation growth.
- Stream banks have construction access with minimal disturbance to the existing ecosystem.

D.6.1.3 Reforest/Install Riparian Buffers

Riparian buffers are vegetative areas along stream banks that can provide numerous ecological benefits. Installing riparian buffers is a common technique used in stream enhancement projects because installing riparian buffers can:

- Prevent stream bank erosion by stabilizing stream banks,
- Provide flood control by absorbing and slowing down flood waters,
- Reduce sedimentation by filtering sediment carried by runoff,
- Improve water quality through filtering nutrients, pesticides, and animal waste from upland runoff,
- Enhance aquatic habitats by providing a stable and diverse environment for fish and other aquatic organisms,
- Provide ecological uplift (reestablish the processes, functions, and links between the aquatic and riparian ecosystems) and improve wildlife habitats by installing native plantings,
- Provide carbon sequestration, and
- Provide improved recreational and aesthetic opportunities by providing an opportunity to make the stream a more attractive and enjoyable feature for the property owner and community.

Riparian buffers may require maintenance to remain effective and prevent invasive species from establishing, especially until the native plantings have become established. Depending on the EU location, riparian buffers can require significant land acquisition or land use conversion because the appropriate riparian buffer width to provide the enhanced ecological benefits from a riparian ecosystem may be larger than the existing riparian buffer width. This may conflict with the property owner's interests or incur high costs for land easements. The effectiveness of riparian buffers may vary depending on the EU's characteristics, such as the stream's flow rates and flow velocities, stream bank slope, soil type, presence of hydric soils, and surrounding land use. For EUs with significant legacy sediment accumulation, riparian buffers as the only treatment alternative will have little impact. In these situations, the riparian buffer will likely be perched high above the stream's base flow water elevation and therefore be disconnected from groundwater flows, limiting the hyporheic exchange in the riparian buffer. Installing a riparian buffer without legacy sediment removal should only be considered for EUs in the Chiques Creek Watershed with minimal legacy sediment accumulation where the riparian corridor is not perched above the stream channel.

For reforesting/installing riparian buffers to be a viable treatment alternative, the following parameters were considered at each EU:

- Riparian corridor is amenable to vegetation growth.
- Existing riparian buffer along the stream corridor is poorly established or nonexistent, such as for EUs where the existing land use is primarily pasture, non-native grass, or mowed grass.
- Riparian corridor can be established consistent with design parameters outlined in PADEP Stormwater Best Management Practices Manual Chapter 6.7.1.

D.6.1.4 Legacy Sediment Removal and Site Restoration

Legacy sediment accumulation can have significant impacts on stream ecosystems, including loss of aquatic biodiversity, reduction in water quality, diminished floodplain soil health, and increased flood risk to disconnected floodplains. Legacy sediment removal is a commonly applied stream enhancement practice for streams affected by significant sedimentation. Legacy sediment removal can improve water quality by removing legacy sediment from the Chiques Creek Watershed, therefore reducing sediment loads, nutrients, and contaminants entering the watershed's waterways. Legacy sediment removal can enhance fish and wildlife habitat by creating diverse and dynamic stream environments, reconnecting the stream to the legacy floodplain, and restoring historic soils and wetlands. Legacy sediment removal can also increase flood storage and conveyance capacity by creating a floodplain bench, decreasing the stream's velocity, and reducing the risk of high-velocity flood damage to downstream properties and infrastructure. Legacy sediment removal can enhance the recreational and aesthetic value of the stream by improving the community's connection to the stream and providing an opportunity to make the stream a more attractive and enjoyable feature for the property owner and community.

Following legacy sediment removal, a main channel and adjacent floodplain bench should be established. The main channel should be designed to contain a low flow storm event and the adjacent floodplain to be activated for larger events. The floodplain's larger conveyance capacity allows kinetic energy to dissipate throughout the floodplain and limits the potential for future stream bank erosion. Having access to a larger floodplain also reduces the amount of shear stress and velocity in the main channel. For EUs where the floodplain area is limited, the main channel should be designed for larger storm events so the bed is able to resist higher shear stresses and velocities. Removing the legacy sediment will further help reconnect the stream to the historic floodplain by providing groundwater connection opportunities, therefore improving the hyporheic exchange along the riparian corridor. This creates an environment for improved water quality and wetland health.

The cost of legacy sediment removal can be high since it requires significant resources for excavation and disposal of the legacy sediment. Obtaining appropriate nearby and cost-effective disposal areas to place the removed sediment can significantly impact the cost of the project. Post-restoration management and monitoring is required to ensure that the native plantings establish properly, and invasive species are managed because legacy sediment removal requires significant disturbance to ecosystems, including temporary loss of riparian vegetation and disruption of aquatic habitats during project construction. Legacy sediment removal can result in short-term increased erosion and instability of the stream banks and bed while vegetation is re-established. The effectiveness of legacy sediment removal may vary based on EU conditions such as slope, soil type, presence of hydric soils, and land use; there is no guarantee that the stream will return to its historic alignment. Regulatory compliance requirements add to the cost and complexity of the project. Legacy sediment removal projects can require significant land acquisition or land use conversion, which may conflict with the property owner's interests or incur high costs.

Following legacy sediment removal, site restoration is required. This site restoration includes revegetation and installation of riparian buffers, which can have similar advantages and disadvantages as outlined in Section D.6.1.3 above. Establishing a riparian buffer after legacy sediment removal is likely to be more effective than riparian buffer installation alone when a significant legacy sediment terrace is present because the riparian corridor is no longer perched above the stream channel and has an opportunity for groundwater connection.

For removing the legacy sediment and site restoration to be a viable treatment alternative, the following parameters were considered at each EU:

- Significant legacy sediment accumulation.

- Stream form is susceptible to erosive velocities that could be reduced through removing the legacy sediment and reconnecting to the historic floodplain.
- Poor existing wetland and riparian buffer quality.
- Soils with benefits associated with legacy sediment removal, such as hydric soils, bedrock, or basal gravel, are present.
- Overall poor habitat quality throughout the floodplain.
- Project area has construction access with minimal disturbance to the existing ecosystem.

D.6.1.5 Mill Dam Removal

Mill dams trap large amounts of sediment, impacting natural water and soil systems. If the dams are breached or removed improperly, they can release sediment downstream, eroding stream banks, degrading stream beds, and impairing water quality. Fifty-three mill dams have been identified in the Chiques Creek Watershed. Of the 53 mill dams, 41 are historic mill dams first documented in atlas maps from the mid-19th century. Forty-six of the 53 mill dams have been breached. Historically, these mill dams have disconnected the stream channel from the historic floodplain.

Five of the 10 EUs are in the proximity of historic mill dams. The mill dams near these five EUs have already been breached, so mill dam removal is not an applicable legacy sediment treatment alternative for any of the 10 EUs included in this evaluation. Mill dam removal may be applicable to a voluntary offered project within the watershed as there are seven remaining.

D.6.2 Selected Treatments for Evaluation Units (EUs)

A summary of the recommended alternative(s) for each EU is provided in Table D.6.1 below.

TABLE D.6.1
SUMMARY OF RECOMMENDED TREATMENT ALTERNATIVES

EU (Number)	Legacy Sediment Volume Estimate (Cubic Yards)	Recommended Treatment Alternative	Stream Length (feet)
1	63,000	Legacy sediment removal and site restoration	2,530
2	65,000	Legacy sediment removal and site restoration	1,110
3	40,000	Legacy sediment removal and site restoration, reforest/install riparian buffer	3,810
4	43,000	Legacy sediment removal and site restoration	2,480

EU (Number)	Legacy Sediment Volume Estimate (Cubic Yards)	Recommended Treatment Alternative	Stream Length (feet)
5	27,000	Legacy sediment removal and site restoration, reforest/install riparian buffer	1,720
6	19,000	Do nothing	2,540
7	17,000	Reforest/install riparian buffer	2,900
8	23,000	Legacy sediment removal and site restoration, reforest/ install riparian buffer, stabilize legacy sediment in place	2,250
9	32,000	Legacy sediment removal and site restoration, reforest/ install riparian buffer, stabilize legacy sediment in place	4,120
10	12,700	Reforest/install riparian buffer	2,520

Figures 1 and 2 show conceptual designs of the recommended land treatment alternatives for EUs 2 and 7, respectively.

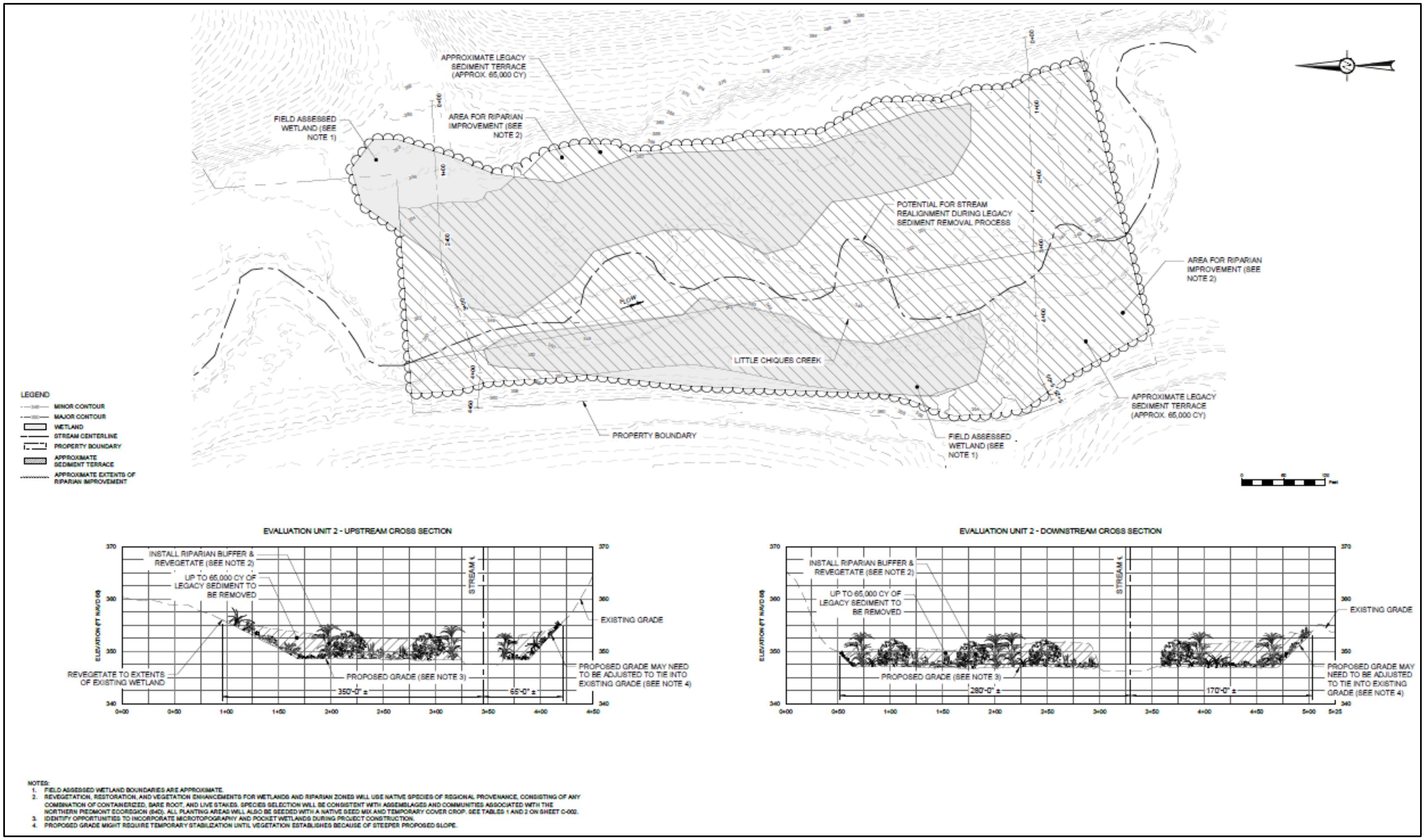

Figure 1 Chiques Creek Legacy Sediment Treatment – Evaluation Unit 2

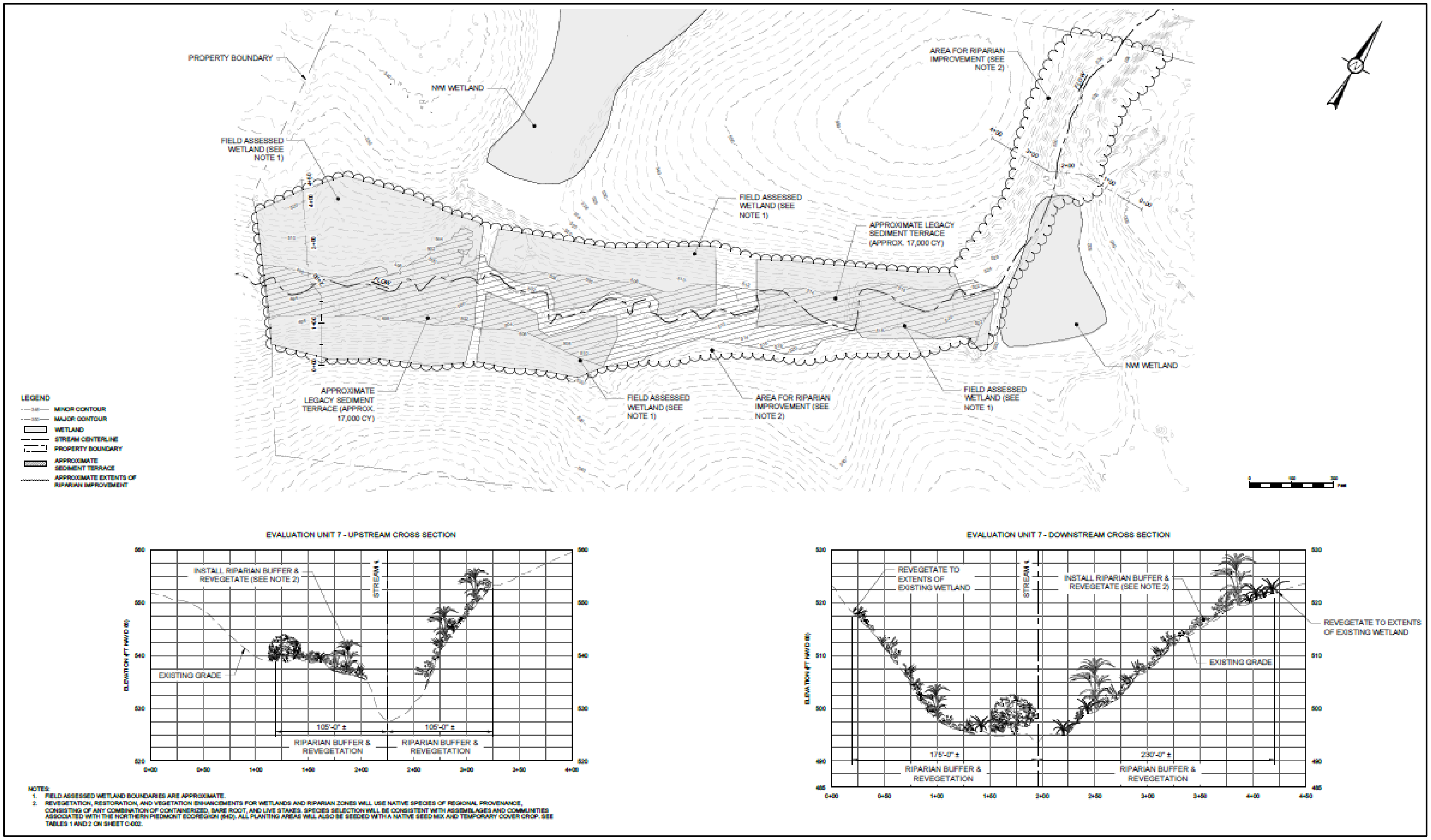

Figure 2 Chiques Creek Legacy Sediment Treatment – Evaluation Unit 7

D.6.3 Conservation Practices and Justification

Planned systems to address water quality relating to legacy sediment stabilization and removal typically are not a stand-alone conservation practice. The conservation practices identified in Section D.6.2 reflect a primary conservation practice that must be included in the conservation system for it to be eligible for inclusion into the program. This is based on the practice's purpose addressing water quality, the Conservation Practice Physical Effects (CPPE), and what is commonly used to address similar resource concerns from other stream improvement projects.

TABLE D.6.2
CHIQUES CREEK PL 83-566 LEGACY SEDIMENT TREATMENT PROGRAM
PRIMARY CONSERVATION PRACTICES

Conservation Practice Standard (CPS)	CPS Code	CPPE Score for Identified Resource Concerns				Justification
		Soil Quality(1)	Water Quality(2)	Animals(3)	Cumulative(4)	
Aquatic Organism Passage	396	1	4	7	12	Practice is to modify or remove barriers that restrict or impede movement or migration of fish or other aquatic organisms. The typical application of this practice in Pennsylvania is small mill dam removal.
Channel Bed Stabilization	584	2	6	1	21	Practice is to maintain or alter channel bed elevation or gradient and to restore natural stream bed function.
Riparian Forest Buffer	391	13	28	10	98	Practice is to plant woody vegetation along riparian corridors.
Riparian Herbaceous Cover	390	4	26	5	78	Practice is to plant non-woody vegetation along riparian corridors.
Stream Bank and Shoreline Protection	580	7	8	4	33	Practice is to prevent the loss of land adjacent to the banks of streams and to reduce the off-site or downstream effects of sediment resulting from bank erosion.

Notes:
1. Considering soil quality resource concerns including Bank Erosion from Streams, Shorelines or Water Conveyance Channels, Soil Organism Habitat Loss or Degradation, and Aggregate Instability.
2. Considering water quality resource concerns including Ponding and Flooding, Nutrients Transported to Surface Water, Pathogens and Chemicals from Manure, Bio-solids or Compost Applications Transported to Surface Water, Sediment Transported to Surface Water, Pesticides Transported to Surface Water, and Elevated Water Temperature.
3. Considering animal resource concerns including Terrestrial Habitat for Wildlife and Invertebrates and Aquatic Habitat for Fish and other Organisms.
4. Considering all resource concerns.

Other conservation practices are often needed to complete a conservation system to address the resource concerns. Table D.6.3 lists those supporting conservation practices that may be needed to accompany a primary conservation practice to complete the system.

TABLE D.6.3
CHIQUES CREEK PL 83-566 LEGACY SEDIMENT TREATMENT PROGRAM
SUPPORTING CONSERVATION PRACTICES

Conservation Practice Standard (CPS)	CPS Code	CPPE Score for Identified Resource Concerns				Justification
		Soil Quality(1)	Water Quality(2)	Animals(3)	Cumulative(4)	
Access Control	472	7	11	7	74	Practice may be used to prevent livestock access to riparian corridor.
Access Road	560	1	1	0	18	Practice may be used to provide access to a stream crossing and crop fields when access is impacted by a legacy sediment project.
Clearing and Snagging	326	2	0	-1	3	Practice is used to remove vegetation along the bank and selective removal of obstructions from streams.
Conservation Cover	327	8	22	4	80	Practice can be used to establish permanent vegetative cover to reduce soil erosion and sedimentation, improve water quality, and/or improve wildlife habitat.
Critical Area Planting	342	8	9	3	63	Practice can be used to establish permanent vegetation on sites that have or are expected to have high erosion rates.
Dike	356	-1	6	-1	9	While not expected to be commonly used, dikes can be used to create impoundments, such as wetland cells, within excavated legacy sediment terraces.
Fence	382	3	3	2	18	May be used to exclude livestock.
Grade Stabilization Structure	410	6	4	2	14	Practice may be needed to connect stream areas where the stream channel is lower downstream due to legacy sediment removal.
Hedgerow Planting	422	0	4	2	31	Practice can be used to establish a line of dense vegetation to provide food, cover, and shade for aquatic organisms in adjacent streams or watercourses.
Heavy Use Area Protection	561	-1	4	0	15	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Lined Waterway or Outlet	468	1	12	-1	23	Practice may be needed to stabilize stream channels after legacy sediment removal.
Livestock Pipeline	516	0	0	0	12	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Mulching	484	4	4	1	34	Mulching may be needed to promote vegetation growth and minimize erosion until vegetation is established.
Obstruction Removal	500	0	0	0	3	Practice may be used to remove and dispose of structures and other works of improvement.
Open Channel	582	4	5	0	12	Practice may be used to construct the stream channel after legacy sediment removal.
Pumping Plant	533	0	5	0	28	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Restoration of Rare or Declining Natural Communities	643	0	4	10	36	Practice could be used to plant the riparian corridor with vegetation targeting RTE species.
Stormwater Runoff Control	570	3	9	0	17	Practice could be used for erosion and sedimentation control on sites under construction.
Stream Crossing	578	5	2	3	14	Practice may be needed to provide access to crop fields or pasture when access is impacted by a legacy sediment project.
Stream Habitat Improvement and Management	395	5	8	8	34	Practice is used to improve or manage stream habitat, but not specifically to address erosion.
Structure for Water Control	587	0	4	4	23	Practice could be used to control water levels in wetlands created/restored within the riparian corridor using a flashboard riser.

Conservation Practice Standard (CPS)	CPS Code	CPPE Score for Identified Resource Concerns Soil Quality(1)	Water Quality(2)	Animals(3)	Cumulative(4)	Justification
Structures for Wildlife	649	0	0	7	7	Practice could be used to install structures that would provide habitat for wildlife such as nesting boxes, brush piles, raptor perches, etc.
Subsurface Drain	606	1	14	0	37	While not expected to be used on most sites, this practice may be needed behind riprap or a wall used to stabilize a stream bank.
Trails and Walkways	575	1	3	4	22	Practice may be used to provide access to a stream crossing and pasture when access is impacted by a legacy sediment project.
Tree/Shrub Establishment	612	12	15	9	98	Used to establish woody plants by planting seedlings or cuttings, normally either bare-root or in pots
Underground Outlet	620	-1	1	0	12	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Water Well	642	0	0	0	17	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Watering Facility	614	4	10	2	36	Practice may be needed to provide protection around a waterer, if a watering system is provided in exchange for removing livestock from a stream that was their only source of water.
Wetland Creation	658	0	10	3	35	Practice creates a wetland where there was historically none. This could be done where legacy sediment has been removed.
Wetland Enhancement	659	0	10	3	32	Practice provides for the enhancement of an existing wetland. This could be done where a wetland exists within a riparian corridor with legacy sediment.
Wetland Restoration	657	0	10	3	34	Practice restores/creates a historic wetland that is no longer present. This could be done where legacy sediment has been removed.
Wetland Wildlife Habitat Management	644	0	6	5	24	Practice is used to develop or manage habitat for wetland wildlife.
Wildlife Habitat Planting	420	0	8	7	24	Practice is used to establish wildlife habitat by planting herbaceous vegetation or shrubs.

Notes:

1. Considering soil quality resource concerns including Bank Erosion from Streams, Shorelines or Water Conveyance Channels, Soil Organism Habitat Loss or Degradation, and Aggregate Instability.
2. Considering water quality resource concerns including Ponding and Flooding, Nutrients Transported to Surface Water, Pathogens and Chemicals from Manure, Bio-solids or Compost Applications Transported to Surface Water, Sediment Transported to Surface Water, Pesticides Transported to Surface Water, and Elevated Water Temperature.
3. Considering animal resource concerns including Terrestrial Habitat for Wildlife and Invertebrates and Aquatic Habitat for Fish and other Organisms.
4. Considering all resource concerns.

Some conservation practices were not included into the proposed program addressing Legacy Sediment because they were not appropriate for the land use, did not align with the purposes of the project, did not address water quality as a purpose of the practice, or other reasons. Table D.6.4 lists the practices that were not selected for inclusion.

TABLE D.6.4
CHIQUES CREEK PL 83-566 LEGACY SEDIMENT TREATMENT PROGRAM
CONSERVATION PRACTICES NOT CONSIDERED FOR INCLUSION

Conservation Practice Standard (CPS)	CPS Code	Justification (1)
Agrichemical Handling Facility	309	Practice does not align with purpose of this project.
Air Filtration and Scrubbing	371	Not appropriate for associated agricultural land use.
Alley Cropping	311	Not appropriate for associated agricultural land use.
Amendments for Treatment of Agricultural Waste	591	Practice does not align with purpose of this project.
Anaerobic Digester	366	Not appropriate for associated agricultural land use.
Animal Mortality Facility	316	Not appropriate for associated agricultural land use.
Annual Forages for Grazing Systems	810	Practice does not align with purpose of this project.
Brush Management	314	While this practice could be used to control vegetation on-site, total site clearing will be needed for legacy sediment removal projects.
Building Envelope Improvement	672	Not appropriate for associated agricultural land use.
Combustion System Improvement	372	Practice does not align with purpose of this project.
Composting Facility	317	Not appropriate for associated agricultural land use.
Conservation Crop Rotation	328	Not appropriate for associated agricultural land use.
Constructed Wetland	656	While a constructed wetland can be used to improve water quality of stormwater runoff or other water flows, it is typically used for wastewater treatment. CPS 658 Wetland Creation is more appropriate for the given project purpose.
Contour Buffer Strips	332	Not appropriate for associated agricultural land use.
Contour Farming	330	Not appropriate for associated agricultural land use.
Contour Orchard and Other Perennial Crops	331	Not appropriate for associated agricultural land use.
Cover Crop	340	Practice is used for seasonal vegetative cover. Vegetation established on legacy sediment sites should be permanent.
Dam	402	Practice does not align with purpose of this project.
Deep Tillage	324	Practice does not align with purpose of this project.
Denitrifying Bioreactor	605	Not appropriate for associated agricultural land use.
Diversion	362	Practice does not align with purpose of this project.
Drainage Water Management	554	Practice does not align with purpose of this project.
Dry Hydrant	432	While wetlands may be created through this project, it is not intended that they will need a dry hydrant to provide water for management.
Early Successional Habitat Development/ Management	647	The main purpose of this practice is wildlife habitat, not water quality.

Conservation Practice Standard (CPS)	CPS Code	Justification [1]
Emergency Animal Mortality Management	368	Not appropriate for associated agricultural land use.
Farmstead Energy Improvement	374	Not appropriate for associated agricultural land use.
Feed Management	592	Not appropriate for associated agricultural land use.
Field Border	386	Not appropriate for associated agricultural land use.
Field Operations Emissions Reduction	376	Not appropriate for associated agricultural land use.
Filter Strip	393	While a filter strip could be used to remove contaminants from overland flow, CPS 390 Riparian Herbaceous Cover or CPS 391 Riparian Forest Buffer is more appropriate for this project.
Firebreak	394	Practice does not align with purpose of this project.
Pasture and Hay Planting	512	It is not expected that the riparian corridors will be pastured or hayed.
Forage Harvest Management	511	Not appropriate for associated agricultural land use.
Forest Stand Improvement	666	Not appropriate for associated agricultural land use.
Forest Trails and Landings	655	Not appropriate for associated agricultural land use.
Fuel Break	383	Not appropriate for associated agricultural land use.
Grassed Waterway	412	Practice does not align with purpose of this project.
Grazing Land Mechanical Treatment	548	Not appropriate for associated agricultural land use.
Groundwater Testing	355	This project does not intend to use groundwater as a source of water for livestock watering, irrigation, wildlife, or other agricultural uses.
Herbaceous Weed Treatment	315	Not appropriate for associated agricultural land use.
High Tunnel System	325	Not appropriate for associated agricultural land use.
Irrigation Pipeline	430	Practice does not align with purpose of this project.
Irrigation Reservoir	436	Practice does not align with purpose of this project.
Irrigation System, Microirrigation	441	Practice does not align with purpose of this project.
Irrigation System, Tailwater Recovery	447	Practice does not align with purpose of this project.
Irrigation Water Management	449	Practice does not align with purpose of this project.
Karst Sinkhole Treatment	527	While the area is underlain by karst geology, it is unlikely to open a sinkhole by removing/stabilizing legacy sediment.
Lighting System Improvement	670	Not appropriate for associated agricultural land use.
Livestock Shelter Structure	576	Not appropriate for associated agricultural land use.
Mine Shaft and Adit Closing	457	Not appropriate for associated agricultural land use.
Monitoring Well	353	Not appropriate for associated agricultural land use.
Nutrient Management	590	As this area will not be used for crop production, fertilizer or manure application is not needed. Therefore, there is not a need for nutrient management.
On-Farm Secondary Containment Facility	319	Not appropriate for associated agricultural land use.
Pest Management Conservation System	595	The purpose of this practice is to reduce pests, not to address water quality concerns caused by nutrients and sediment.
Phosphorus Removal System	782	While this practice can be used to remove dissolved phosphorus from ground water, this program focuses on sediment and sediment-bound phosphorus.

Conservation Practice Standard (CPS)	CPS Code	Justification [1]
Pond	378	It is not expected that ponds will be created by this program.
Pond Sealing or Lining - Compacted Soil Treatment	520	It is not expected that ponds will be created by this program.
Pond Sealing or Lining - Geomembrane or Geosynthetic Clay Liner	521	It is not expected that ponds will be created by this program.
Prescribed Burning	338	It is not expected that this practice would be needed to improve riparian habitat.
Prescribed Grazing	528	Livestock would be excluded from the riparian area, making this practice unnecessary.
Residue and Tillage Management, No Till	329	Not appropriate for associated agricultural land use.
Residue and Tillage Management, Reduced Till	345	Not appropriate for associated agricultural land use.
Road/Trail/Landing Closure and Treatment	654	Practice does not align with purpose of this project.
Roof Runoff Structure	558	Not appropriate for associated agricultural land use.
Roofs and Covers	367	Not appropriate for associated agricultural land use.
Sediment Basin	350	While practice may be installed as a temporary feature to control sediment runoff, it is not planned that a permanent sediment basin would be permanently located on a project.
Shallow Water Development and Management	646	This practice can be used to regulate water levels for wildlife habitat. It is expected that management will not be needed for these projects.
Short Term Storage of Animal Waste and Byproducts	318	Not appropriate for associated agricultural land use.
Spring Development	574	This practice is used to provide water for livestock. There should not be livestock within the riparian corridor.
Sprinkler System	442	Practice does not align with purpose of this project.
Stripcropping	585	Not appropriate for associated agricultural land use.
Surface Drain, Field Ditch	607	Surface drainage not planned for project.
Surface Drain, Main or Lateral	608	Surface drainage not planned for project.
Terrace	600	Not appropriate for associated agricultural land use.
Tree/ Shrub Site Preparation	490	This practice is meant for preparing new sites for shrubs, not where the site will have earth moving already occurring.
Tree/Shrub Pruning	660	Practice does not align with purpose of this project.
Upland Wildlife Habitat Management	645	This practice focuses on the uplands instead of riparian floodplains.
Vegetated Treatment Area	635	Not appropriate for associated agricultural land use.
Waste Facility Closure	360	Not appropriate for associated agricultural land use.
Waste Gasification Facility	735	Not appropriate for associated agricultural land use.
Waste Recycling	633	Practice does not align with purpose of this project.
Waste Separation Facility	632	Not appropriate for associated agricultural land use.
Waste Storage Facility	313	Not appropriate for associated agricultural land use.
Waste Transfer	634	Not appropriate for associated agricultural land use.
Waste Treatment	629	Not appropriate for associated agricultural land use.
Waste Treatment Lagoon	359	Not appropriate for associated agricultural land use.

Conservation Practice Standard (CPS)	CPS Code	Justification (1)
Water and Sediment Control Basin	638	While practice may be installed as a temporary feature to control sediment runoff, it is not planned that a permanent sediment basin would be permanently located on a project.
Well Decommissioning	351	Practice does not align with purpose of this project.
Windbreak/Shelterbelt Establishment	380	Practice does not align with purpose of this project.
Woody Residue Treatment	384	Practice does not align with purpose of this project.

Note:

1. Not appropriate for the associated agricultural land use determined from RMS Planning Tool – FY25 National.xls. Associated agricultural land use includes land associated with farms and ranches that are not purposefully managed for food, forage, or fiber and are typically associated with nearby production and/or conservation lands. This could include incidental areas such as idle center pivot corners, odd areas, ditches and watercourses, riparian areas, field edges, seasonal and permanent wetlands, and other similar areas.

D.7 Economic Evaluation

An economic analysis was performed for the Plan-PEA to calculate the estimated costs and benefits of the program. To inform the economic analysis for the Plan-PEA, cost and benefit calculations were completed for the ten EUs investigated to determine the average cost to install treatment practices per linear foot of stream, site data from the ten EUs were also used to determine monetized benefits occurring from the proposed land treatment practices. Additional details about the cost and benefit calculations, and how the EU investigations informed the development of the Plan-PEA economic analysis are presented in the following sections.

Since specific projects included in the program will be determined through an application and selection process, the costs and benefits calculated for the Legacy Sediment Program are based on the amount of funding available for the program. The available construction funding includes $15 million provided through PL 83-566 and $5 million cost-share from the Sponsoring Local Organization, making the total funding for the program $20 million. The construction funding of $20 million determined the length of stream land treatment practices that could be installed throughout the watershed.

Disbursement of construction funding for installation of land treatment practices was assumed to occur in equal amounts of $1,970,000 million annually for the first 10 years of the program. Land treatment practices will be installed in ten construction sequences during years one through ten. In addition to the base construction cost of $1,970,000 million per year, installation of land treatment practices is expected to require a three-year establishment period, in which it is assumed that 0.5 percent of the base construction cost (or $10,000 per year) will be required for construction access and event management during the period when vegetation is being established. It is assumed that construction will occur during the first 10 years of the program and that the land treatment practices installed will have a useful life of 20 years in which calculated benefits will accrue. Thus, the economic analysis was performed for a total of 30 years.

The base construction costs, installation costs during the establishment period, as well as costs for engineering design, project administration, extended operation and maintenance, and other associated fees were included in the cost analysis to determine an estimated total cost of the program of $24,646,000. Additional details discussing the calculated costs are presented in Section D.7.1, and the amortization of costs for the Legacy Sediment Program is presented in Table D.7.2.

Benefits for reductions in sediment, nitrogen, phosphorus, and land lost to erosion were calculated for the program over the 20-year lifespan of the installed land treatment practices for each construction sequence. The total estimated benefits provided by the program were calculated to be $34,802,000. Additional details discussing the calculated benefits are provided in Section D.7.2, and the amortization of benefits for the Legacy Sediment Program is presented in Table D.7.1.

D.7.1 Cost Determination

To determine the length of stream that land treatment practices could be installed on with the $20 million construction budget, detailed studies of 10 EUs within the watershed were used to calculate the average installation cost per linear foot of stream. By averaging the base construction cost for installation of each land treatment practices per linear foot of stream for the 10 EUs, the average base construction cost for each system, per foot of streambank length, was determined. A 25 percent contingency was then assumed.

The first three years following construction are considered the establishment period and are included in the installation cost. After the establishment period, operation and maintenance (O&M) activities are anticipated to be required once every five years and are assumed to be 0.5 percent of the total base construction cost. Costs associated with post-establishment O&M will be defined through an agreement between the SLO and the landowner.

Costs for technical assistance and engineering design were assumed to be 15 percent of the base construction cost. Costs related to project administration were estimated to be a total of $1 million for the program. Additional project related costs incurred by the SLO include $5,000 for engineering related tasks and $241,000 to cover any potential real estate appraisal fees, legal fees, survey costs, and flowage easements needed.

D.7.2 Benefits Determination

Monetized benefits were calculated for reductions in sediment, nitrogen, phosphorous, and land lost to erosion. Reductions of these parameters were calculated based on the total length of stream that land treatment practices could be installed on with the funding available. To determine the sediment loading reductions expected to occur from the Legacy Sediment Program, an average erosion rate reduction per linear foot of stream was calculated to be 0.039 cubic yards per year based on the evaluation of the 10 EUs. With the program expected to fund installation of land treatment practices on 29,150 linear feet of stream, the total erosion rate reduction was calculated to be 853 cubic yards of sediment per year. This volumetric erosion rate reduction was converted to a mass of sediment using the average density of soil at the 10 EUs (66.8 pounds per cubic foot) to obtain an erosion reduction rate of 1,025 tons per year. This erosion reduction rate was used as the basis for evaluating reductions in sediment, nitrogen, phosphorus, and land lost reduction benefits expected to occur from the Legacy Sediment Program.

Annualized benefits for reductions in sediment, nitrogen, phosphorus, and land lost to erosion were estimated based on the erosion reduction rate of 1,025 tons per year described above. This erosion reduction rate of 1,025 tons per year corresponds to the reduction in sediment load to the watershed. To determine the reduction of nitrogen and phosphorus that would occur, the erosion rate reduction was multiplied by the average nitrogen and phosphorus concentrations of the soil obtained from soil sampling conducted at the 10 EUs. From the soil samples taken from the 10 EUs, the average concentrations of nitrogen and phosphorus are 547.6 and 147.7 mg/kg of soil, respectively. Using this methodology, the annual reductions in nitrogen and phosphorus were calculated to be 5,454 pounds of nitrogen per year and 1,471 pounds of phosphorus per year. The social benefits of pollutant reductions presented in a study of water quality benefits in the Chesapeake Bay Watershed (Choi et al., 2019) were used to assign monetary values to the reductions in sediment, nitrogen, and phosphorus. The monetized social benefits for sediment, nitrogen, and phosphorus reductions presented in the referenced study were adjusted to 2025 dollars, resulting in the following monetized net benefits: \$20.34 per pound of nitrogen reduced, \$246.88 per pound of phosphorus reduced, and \$0.50 per pound of sediment reduced. Annual benefits for reductions in sediment, nitrogen, and phosphorus were applied to the 30-year benefit analysis starting in of the year after construction is completed and continuing yearly throughout the 20-year project life for each construction sequence.

Land lost from erosion was also calculated as a benefit provided by the Legacy Sediment Program. To calculate the reduction in land lost to erosion, the expected reduction in erosion rate (1,025 tons per year) was multiplied by the average depth of legacy sediment terraces determined during the analysis of the 10 EUs to estimate the area of land lost per year. This value was then multiplied by the estimated cost of land in Lancaster County, Pennsylvania, which was assumed to be $30,000 per acre. This annual land lost reduction benefit was applied to the 30-year benefit analysis starting in the year after construction is completed and continuing yearly throughout the 30-year project life for each construction sequence.

One-time benefits for nitrogen and phosphorus reductions are expected to occur with projects that include legacy sediment removal as a land treatment practice. By removing the nutrient-laden sediment from the floodplain, the benefit of nutrient reduction is accomplished. To estimate the volume of legacy sediment that would be removed during the program, a unit volume of sediment per one foot length of stream was first calculated. The total volume of legacy sediment terraces in the watershed was estimated from data provided by the WSI, and the unit volume of sediment per foot of stream was determined by dividing the total volume of sediment obtained from the WSI data by the total length of streams containing legacy sediment terraces in the watershed. The unit volume of sediment per stream length was calculated to be approximately 89.8 ft^3/ft. With the Legacy Sediment Program expected to fund the installation of treatment practices along 29,150 linear feet of stream, the total volume of sediment along this length was estimated to be at least 96,970 cubic yards. Since one-time benefits for nutrient reductions only occur when sediment removal is included with the proposed land treatment practices, the volume of sediment to be removed was estimated by assuming 40 percent of projects would include legacy sediment removal. Using the methodology described, it was estimated that at least38,800 cubic yards of legacy sediment will be removed from the watershed. To determine the monetized benefits for this one-time removal of sediment, the volume of sediment was multiplied by the average concentrations of nitrogen and phosphorus to determine the amount of nutrients removed. Then, the amount of nitrogen and phosphorus removed was multiplied by their respective net social benefit value presented in the Choi, et al. study (2019) to get the total monetized benefit for each nutrient. Since the installation of treatment practices is anticipated to occur every year for the first ten years of the program, the one-time benefits occurring from sediment removal were distributed across the ten-year installation period. These one-time nutrient removal benefits were applied to the 30-year benefit analysis in the year installation occurs for each construction sequence.

D.7.3 Benefit and Cost Analysis

Using the methodology described above, the average annualized total costs and benefits for the Legacy Sediment Program were calculated to be $1,268,000 and $1,776,000, respectively. The average annualized costs and benefits were used to calculate a benefit-cost ratio of 1.40 for the program. Table D.7.1 and Table D.7.2 provide the 30-year benefit and cost analysis, respectively, using a 20-year project life and a discount rate of 3.0 percent.

To inform planning and decision making for the Legacy Sediment Program, economic analyses were previously completed for the 10 EUs within the Chiques Creek watershed. Benefit-cost ratios for each EU ranged from 0.08 to 3.08. An average of all benefit-cost ratios for the 10 EUs was calculated to be 1.27. A weighted benefit-cost ratio (weighting each benefit-cost by the total length of stream for each EU) calculates to be 1.28. EUs that included the removal of legacy sediment (CPS 584) as a primary treatment practice provided greater benefit-cost ratios than projects that only included reforestation/installation of a riparian buffer (CPS 391 and CPS 390). This finding can be used during the project selection process to ensure projects selected for funding offer the greatest net benefits. A summary of the benefit-cost ratios calculated for each EU is presented in Table D.7.3 below.

When considering the benefit-cost ratio, an overall approach is more appropriate when conducting a programmatic approach to watershed protection. Site conditions will dictate one particular best management practice over another based on a variety of conditions which might include heavy/light concentration of pollutants, high/low construction costs, availability of riparian buffer, among other factors. Project benefits can be maximized by selecting appropriate land treatment practices for each individual site.

Based on the findings from the programmatic economic analysis and the economic analyses conducted for the 10 EUs, it is expected that the Legacy Sediment Program will result in overall net benefits.

TABLE D.7.1
BENEFIT ANALYSIS
(CHIQUES CREEK WATERSHED – 30-YEAR PROJECT LIFE)

Year	N Removal Benefit	P Removal Benefit	Sed Removal Benefit	Land Lost from Erosion Reduction Benefit	One Time Benefit of N Removal from Construction	One Time Benefit of P Removal from Construction	Total Benefits
1	$0	$0	$0	$0	$284,194	$930,361	$1,214,554
2	$8,325	$27,252	$77,358	$346	$284,194	$930,361	$1,327,836
3	$16,649	$54,505	$154,716	$692	$284,194	$930,361	$1,441,117
4	$24,974	$81,757	$232,075	$1,039	$284,194	$930,361	$1,554,399
5	$33,299	$109,010	$309,433	$1,385	$284,194	$930,361	$1,667,681
6	$41,623	$136,262	$386,791	$1,731	$284,194	$930,361	$1,780,962
7	$49,948	$163,515	$464,149	$2,077	$284,194	$930,361	$1,894,244
8	$58,273	$190,767	$541,508	$2,424	$284,194	$930,361	$2,007,525
9	$66,598	$218,020	$618,866	$2,770	$284,194	$930,361	$2,120,807
10	$74,922	$245,272	$696,224	$3,116	$284,194	$930,361	$2,234,088
11	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
12	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
13	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
14	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
15	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
16	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
17	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
18	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
19	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
20	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
21	$83,247	$272,524	$773,582	$3,462	$0	$0	$1,132,816
22	$74,922	$245,272	$696,224	$3,116	$0	$0	$1,019,534
23	$66,598	$218,020	$618,866	$2,770	$0	$0	$906,253
24	$58,273	$190,767	$541,508	$2,424	$0	$0	$792,971
25	$49,948	$163,515	$464,149	$2,077	$0	$0	$679,690
26	$41,623	$136,262	$386,791	$1,731	$0	$0	$566,408
27	$33,299	$109,010	$309,433	$1,385	$0	$0	$453,126
28	$24,974	$81,757	$232,075	$1,039	$0	$0	$339,845
29	$16,649	$54,505	$154,716	$692	$0	$0	$226,563
30	$8,324.70	$27,252.44	$77,358.24	$346.22	$0.00	$0.00	$113,281.59
Total:	**$1,664,939**	**$5,450,488**	**$15,471,648**	**$69,243**	**$2,841,936**	**$9,303,606**	**$34,801,860**
Average Annual Benefits:	**$84,944**	**$278,080**	**$789,352**	**$3,533**	**$144,993**	**$474,663**	**$1,775,565**

Note:
1. The discount rate is 0.03 (3 percent).
2. N = nitrogen, P = phosphorous, Sed = sediment

Benefit Cost Ratio =	**1.40**

TABLE D.7.2
COST ANALYSIS
(CHIQUES CREEK WATERSHED – 30-YEAR PROJECT LIFE)

Year	Engineering / Technical Assistance	Real estate appraisal fees, legal fees, survey costs, flowage easements	Project Administration	Installation Cost	O&M Cost	Total Project Cost
1	$300,500	$24,100	$20,000	$0	$0	$344,600
2	$300,500	$24,100	$40,000	$2,000,000	$0	$2,364,600
3	$300,500	$24,100	$60,000	$2,010,000	$0	$2,394,600
4	$300,500	$24,100	$80,000	$2,020,000	$0	$2,424,600
5	$300,500	$24,100	$100,000	$2,030,000	$0	$2,454,600
6	$300,500	$24,100	$100,000	$2,030,000	$0	$2,454,600
7	$300,500	$24,100	$100,000	$2,030,000	$0	$2,454,600
8	$300,500	$24,100	$100,000	$2,030,000	$0	$2,454,600
9	$300,500	$24,100	$100,000	$2,030,000	$0	$2,454,600
10	$300,500	$24,100	$100,000	$2,030,000	$10,000	$2,464,600
11	$0	$0	$80,000	$2,030,000	$10,000	$2,120,000
12	$0	$0	$60,000	$30,000	$10,000	$100,000
13	$0	$0	$40,000	$20,000	$10,000	$70,000
14	$0	$0	$20,000	$10,000	$10,000	$40,000
15	$0	$0	$0	$0	$20,000	$20,000
16	$0	$0	$0	$0	$20,000	$20,000
17	$0	$0	$0	$0	$20,000	$20,000
18	$0	$0	$0	$0	$20,000	$20,000
19	$0	$0	$0	$0	$20,000	$20,000
20	$0	$0	$0	$0	$20,000	$20,000
21	$0	$0	$0	$0	$20,000	$20,000
22	$0	$0	$0	$0	$20,000	$20,000
23	$0	$0	$0	$0	$20,000	$20,000
24	$0	$0	$0	$0	$20,000	$20,000
25	$0	$0	$0	$0	$10,000	$10,000
26	$0	$0	$0	$0	$10,000	$10,000
27	$0	$0	$0	$0	$10,000	$10,000
28	$0	$0	$0	$0	$10,000	$10,000
29	$0	$0	$0	$0	$10,000	$10,000
30	$0	$0	$0	$0	$0	$0
Total:	**$3,005,000**	**$241,000**	**$1,000,000**	**$20,300,000**	**$300,000**	**$24,846,000**
Average Annual Costs:	**$153,313**	**$12,296**	**$51,019**	**$1,035,691**	**$15,306**	**$1,267,625**

Note:

1. The discount rate is 0.03 (3 percent).
2. Land treatment practices will be installed in construction sequences during years 1-10.
3. Land treatment practices are expected to have a useful life of 20 years. Including the 10 year installation period, the program length will be 30 years.

TABLE D.7.3
PRESENT VALUE NET BENEFITS FOR 10 EVALUATION UNITS (EUS)
(CHIQUES CREEK WATERSHED – 30-YEAR PROJECT LIFE)

EU (Number)	Recommended Treatment Alternative	Estimated Annual Benefit	Present Value Benefit (1) (2)	Present Value Total Cost (3)(4)	Present Value Net Benefits	Benefit-Cost Ratio(4)
1	Legacy sediment removal and site restoration	$30,209	$1,508,348	$6,866,143	-$5,357,795	0.22
2	Legacy sediment removal and site restoration	$19,307	$7,447,971	$2,418,127	$5,029,844	3.08
3	Legacy sediment removal and site restoration, reforest/install riparian buffer	$18,623	$5,505,818	$1,889,711	$3,616,107	2.91
4	Legacy sediment removal and site restoration	$1,982	$1,068,864	$1,576,923	-$508,059	0.68
5	Legacy sediment removal and site restoration, reforest/install riparian buffer	$5,480	$2,359,870	$1,174,301	$1,185,569	2.01
6	Do nothing	$0	$0	$0	$0	1
7	Reforest/install riparian buffer	$1,462	$25,461	$341,045	-$315,584	0.08
8	Legacy sediment removal and site restoration, reforest/install riparian buffer, stabilize legacy sediment in place	$2,196	$182,435	$784,743	-$602,308	0.23
9	Legacy sediment removal and site restoration, reforest/install riparian buffer, stabilize legacy sediment in place	$10,459	$3,069,755	$1,459,062	$1,610,693	2.10
10	Reforest/install riparian buffer	$1,257	$21,895	$150,729	-$128,834	0.15
				AVERAGE BENEFIT COST		1.27
				AVERAGE BENEFIT COST (WEIGHTED)		**1.28**

Notes:
1. Present Value Coefficient = 17.908
2. Discount Rate = 0.03 (National Bulletin 200-23-2)
3. PV Total Cost includes operation and maintenance costs and design and permitting costs
4. Analysis period = 30 years for evaluation of the 10 EUs. The period of analysis for the Legacy Sediment Program was refined to be 30 years to account for the 10-year installation period and the 20-year expected life of the installed land treatment practices.

D.8 References

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