Walker Run Geomorphic Assessment

Prepared for:

PPL Bell Bend Nuclear Power Plant
Salem Township, Luzerne County, PA

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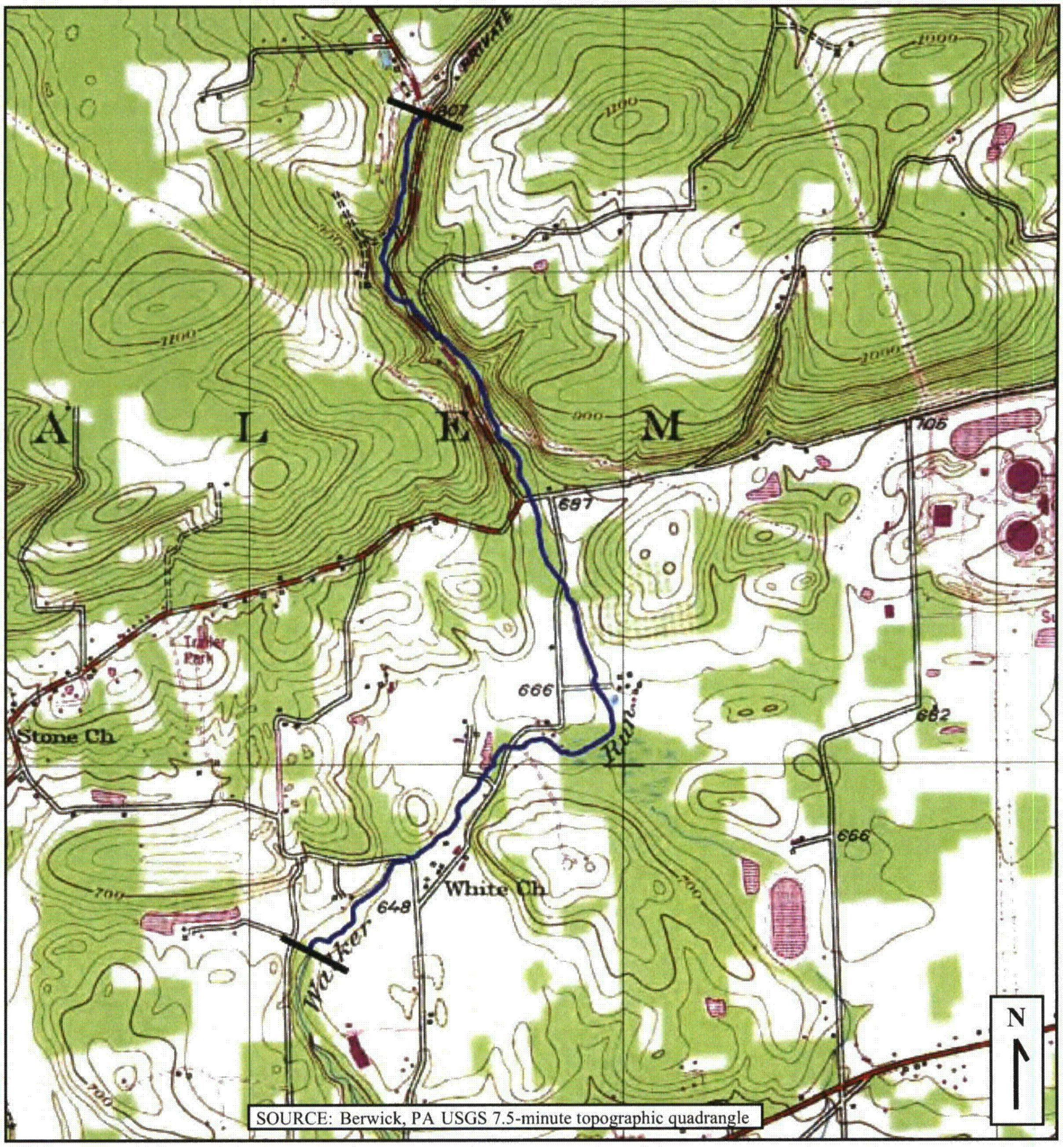
I. INTRODUCTION

The following report outlines the current conditions, in terms of stability, of the Walker Run stream system located in Salem Township, Luzerne County, PA and more specifically located within the proposed PP&L Bell Bend Nuclear Power Plant (BBNPP) site. See Figure 1 for the approximate limits of the stream stability assessment performed along Walker Run.

Stream stability can be determined through many assessment protocols. The best way to obtain a reliable measure of the long-term stability of a stream channel is to monitor the channel over a period of time and see how it responds to different flow events and conditions. The true definition of stability is that the channel can convey and transport the sediment load of the watershed without degrading and/or aggrading over time in the present geologic conditions. Stability can be assessed through photo-documentation or surveying of the stream channel cross section and longitudinal profile, repeating the procedure at some period in the future, and then comparing the two sets of data to see if and how the channel has changed.

There are, however, other methods that allow one to evaluate the current conditions of the stream and predict with some degree of confidence the degree and trends of channel instability and adjustment. These methods are based on various geomorphic features. For this project, we used two protocols to both quantitatively and qualitatively evaluate and predict the level of channel stability/instability. They included performing a Level II Geomorphic Characterization and using the David Rosgen Level III Bank Erodibility Hazard Index Rating (BEHI) methodology.

We can reasonably predict the degree of channel instability through the use of these visual and geomorphic assessment protocols. However, the rate of channel instability is a factor that is typically affected by varying flow events and other factors. Overall stability is something that needs to be evaluated over a period of time that will consider these additional factors of varying flow events, freeze thaw actions, anthropogenic influences such as channel changes and land-clearing, and even changes in the sediment regime through natural processes. By installing bank pins at surveyed cross section sites and resurveying actual channel conditions in the future, we will be able to compare the initial predictions with the actual conditions to obtain a more accurate prediction of channel stability and future adjustment.



Legend

Assessment Reach

Scale

1 inch equals 2000 feet

500 0 1000 2000

FIGURE 1. Limits of Geomorphic Assessment along Walker Run
PPL Bell Bend Nuclear Power Plant, Salem Township, Luzerne County, PA

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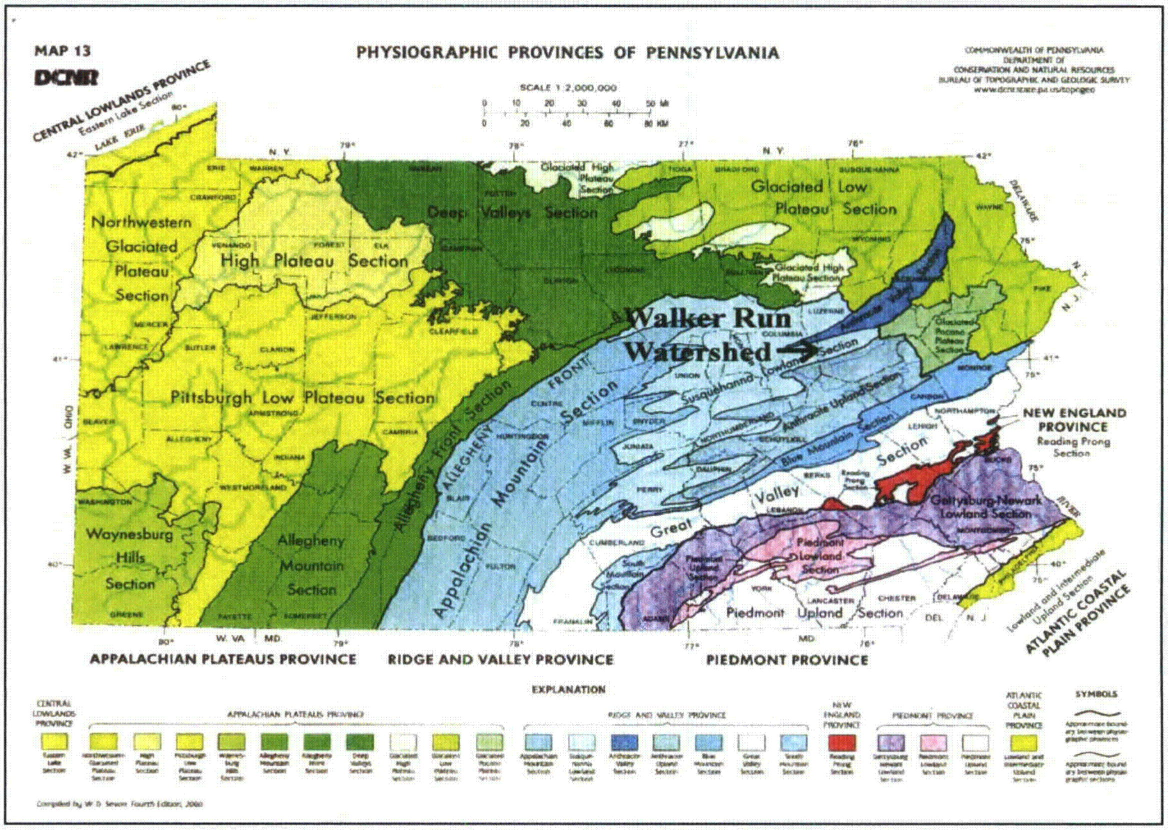
II. PHYSIOGRAPHIC REGION, HYDROLOGY, GEOLOGY, AND EXISTING LAND USE

Physiographic Region

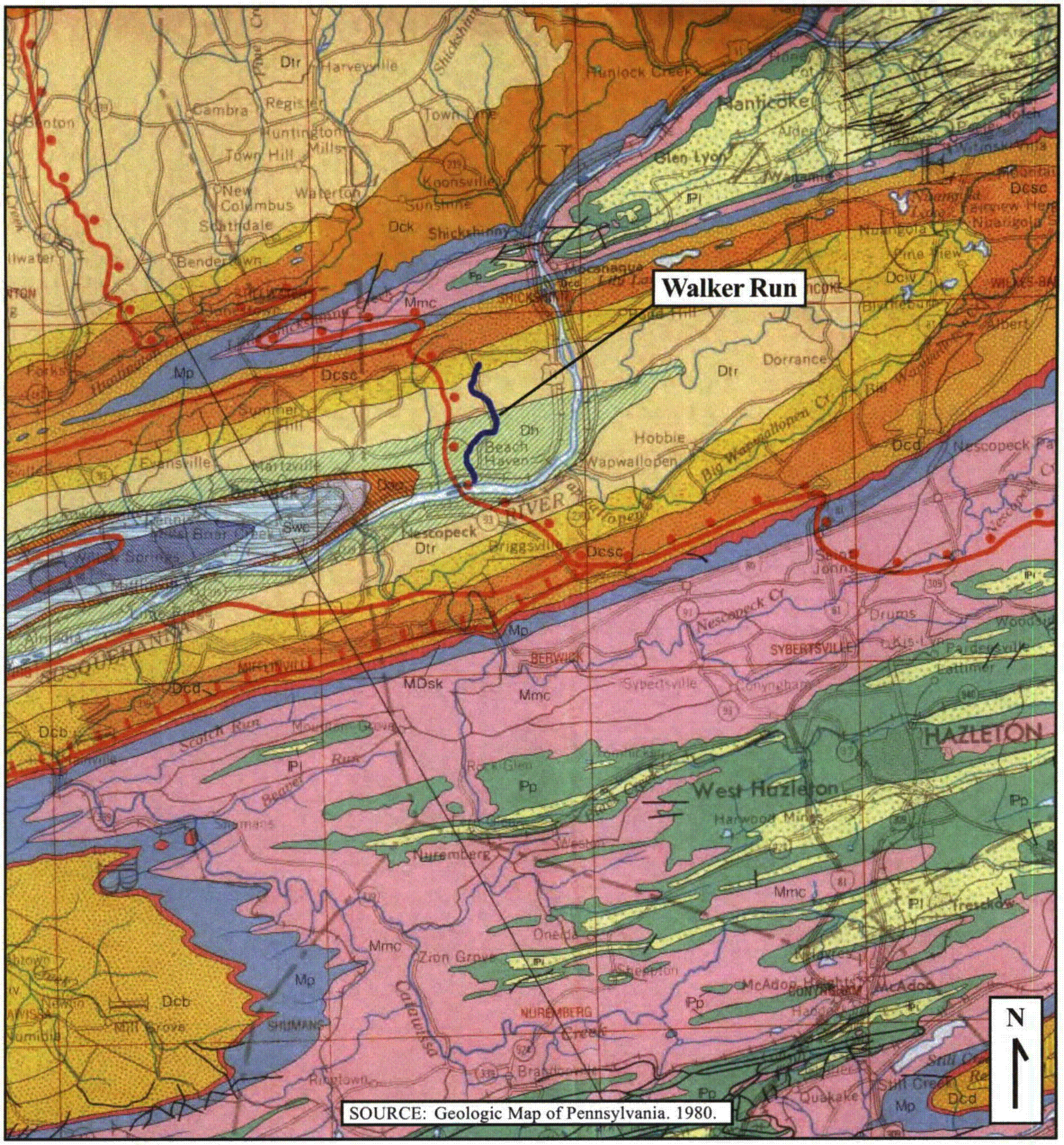
The Walker Run watershed and project site controlled by Pennsylvania Power and Light (PPL), lies entirely within the Susquehanna Lowland Section of the Ridge and Valley Physiographic Region (see *Figure 2*). The Susquehanna Lowland Section consists of low to moderately high, linear ridges, linear valleys, and the Susquehanna River valley. The geologic structure is open and closed plunging folds having narrow hinges and planar limbs with the underlying rock consisting mainly of sandstone, siltstone, shale, conglomerate, limestone, and dolomite.

Figure 2. Physiographic Provinces Map of Pennsylvania



Hydrology

Walker Run is a perennial stream that is listed as a *Cold Water Fishery by PADEP Chapter 93 Water Quality Standards.* Multiple springs, rainfall, and snowmelt influence the stream flow. Bankfull and higher flows may occur as a result of a variety of rain events, including rain or snow, frontal storm events, and tropical storms. The drainage area to the end of the Walker Run project reach is approximately 2.87 square miles. Walker Run confluences with the Susquehanna River approximately one mile downstream of the project area.



Geologic Formations within the Walker Run watershed include:

Dh = Hamilton Group	Dciv = Irish Valley Member
Dtr = Trimmers Rock Formation	Dcsc = Sherman Creek Member

(see *Figure Xb. Geology Map Legend* for descriptions)

Location:
41°05'8.56"N, 76°10'3.79"W

Scale:
1:250,000

FIGURE 3a. Geology Map

Walker Run Geomorphic Assessment, Salem Twp., Luzerne County, PA

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AGE

younger

older

PLEISTOCENE

NORTH-CENTRAL AND NORTHEASTERN PENNSYLVANIA

Wisconsinan Stage

Woodfordian Substage

Border of Olean ice advance

Altonian Substage

Border of Warrensville ice advance

Illinoian Stage

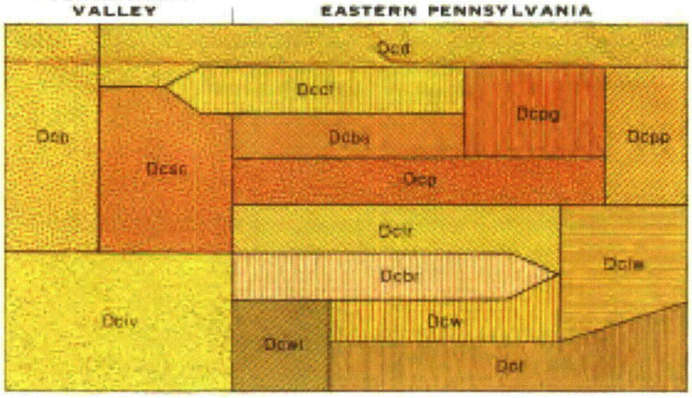
Border of Muncy ice advance

DEVONIAN (UPPER)

CENTRAL AND EASTERN PENNSYLVANIA

Dck — CATSKILL FORMATION, UNDIVIDED

Succession of grayish-red sandstone, siltstone, and shale, generally in fining-upward cycles; some gray sandstone and conglomerate.



SHERMAN CREEK MEMBER (Dcsc)

Alternating grayish-red siltstone and claystone in poorly defined, fining-upward cycles, and minor intervals of gray sandstone; laterally equivalent to Berry Run, Sawmill Run, Packerton, and Long Run Members.

IRISH VALLEY MEMBER (Dciv)

Nonmarine, gray and grayish-red sandstone and grayish-red claystone interbedded with minor, thin light-olive-gray marine siltstone, arranged in fining-upward cycles. Lower part of member has conglomeratic sandstones.

Dtr — TRIMMERS ROCK FORMATION

Olive-gray siltstone and shale, characterized by graded bedding; marine fossils, some very fine grained sandstone in northeast; black shale of Harrell Formation at base in Susquehanna Valley.

DEVONIAN (MIDDLE & LOWER)

Dh — HAMILTON GROUP

Dmh — MAHANTANGO FORMATION

Gray, brown, and olive shale and siltstone; marine fossils. Includes following members, in descending order: Tully—limestone or calcareous shale; Sherman Ridge, Montebello (sandstone), Fisher Ridge, Dalmatia, and Turkey Ridge. In south-central Pennsylvania, includes Clearville, Frame, Chaneysville, and Gander Run Members. Characterized by coarsening-upward cycles.

Dm — MARCELLUS FORMATION

Black, carbonaceous shale; sparse marine fauna and siderite concretions. Contains local limestone ("Purcell") member. Tioga bentonite included at base in eastern Pennsylvania.

FIGURE 3b. Geology Map Legend

Walker Run Geomorphic Assessment, Salem Twp., Luzerne County, PA

Geology and Sediment Supply

Four distinct geologic formations exist within the Walker Run watershed upstream of the project area (see *Figure 3a and 3b*). Table 1 provides a description of each geologic formation. The underlying geology of the headwaters upstream of the project site consists of east to west trending bands of the upper Devonian-age Sherman Creek and Irish Valley Members. The Sherman Creek Member is composed of alternating grayish-red siltstone and claystone as well as minor intervals of gray sandstone. The Irish Valley Member consists of nonmarine, gray and grayish red sandstone and grayish-red claystone interbedded with minor, thin light-olive-gray marine siltstone. The underlying geology of the upstream portion of the project site consists of an east to west trending band of the upper Devonian-age Trimmers Rock Formation, which is composed of olive-gray siltstone and shale. The underlying geology of the downstream portion of the project site consists of an east to west trending band of the lower and middle Devonian-age Hamilton Group. The Hamilton Group is made up of two formations: the Mahantango Formation and the Marcellus Formation. The Mahantango Formation is composed of gray, brown and olive shale and siltstone while the Marcellus Formation is composed of black, carbonaceous shale.

Much of the bedload material within the project reach has originated from the physical weathering of the geologic formations described above over time. Additional sediment supply is generated from large accumulations of fine-grained silts and clay deposited in the valley bottoms and behind post-settlement dams.

Table 1. Geologic Formations located within the Walker Run Watershed.

Name	Abbrev.	Age	Description
Hamilton Group	Dh	Middle & Lower Devonian (417 million yrs)	Mahantango Formation – gray, brown, and olive shale and siltstone; marine fossils. Includes following members, in descending order: Tully-limestone or calcareous shale; Sherman Ridge, Montebello (sandstone), Fisher Ridge, Dalmatia, and Turkey Ridge. Marcellus Formation – Black carbonaceous shale; sparse marine fauna and siderite concretions. Contains local limestone member (Purcell). Tioga bentonite included at base in eastern Pennsylvania.
Trimmers Rock Formation	Dtr	Upper Devonian (370 million yrs)	Olive-gray siltstone and shale, characterized by graded bedding; marine fossils; some very fine grained sandstone in northeast; black shale of Harrell Formation at base in Susquehanna Valley
Irish Valley Member	Dciv	Upper Devonian (370 million yrs)	Nonmarine, gray and grayish-red sandstone and grayish-red claystone interbedded with minor, thin, light-olive-gray marine siltstone; arranged in fining upward cycles. Lower part of member has conglomerate sandstones.
Sherman Creek Member	Dcsc	Upper Devonian (370 million yrs)	Alternating grayish-red siltstone and claystone in poorly defined, fining upward cycles, and minor intervals of gray sandstone' laterally equivalent to Berry Run, Sawmill Run, Packerton, and Long Run Members

The surficial materials within the watershed consist of sandy and sandy-to-silty glacial diamicts. Sandy glacial diamict has a moderate to abundant silt and sand matrix and minimal clay. The diamict overlies mainly sandstone bedrock. Thickness is variable; diamict greater than 3 feet thick covers 25 to 50 percent of the area of occurrence in northeast Pennsylvania.

Deposits less than 3 feet thick are common. The diamict has minimal weathering, thin soil development, and generally has suffered little erosion. Sandy to silty glacial diamict has variable amounts of sand and silt in the matrix and generally small amounts of clay. Thickness is variable; diamict greater than 3 feet thick covers only 10 to 25 percent of the area of occurrence, and there is no diamict on the remaining surface. The diamict has been moderately weathered, has moderately thick soil development, and has been moderately to severely eroded.

Existing Land Use

The upper Walker Run watershed consists of rural residential homes with forested corridors along Walker Run and some minor agriculture practices. Within the upper portion of the watershed, the Walker Run system is moderately steep with gentle side slopes and valley floors that are composed of soils from alluvium and colluvium material. This condition is typical for the upper watershed down to the Beach Grove Road bridge crossing.

The middle portion of the watershed, specifically where the proposed PPL BBNPP site is proposed, is currently open farmland and meadow areas with forested areas intermixed. The middle portion of the watershed lies within a valley floor that is gently sloped with a well-developed floodplain in soils that are mainly composed of alluvial soils.

The lower portion of the watershed consists of the small town of Beach Haven, a more urban residential setting. This portion of the watershed is similar to the upper watershed, with moderately steep slopes and a valley floor that consist of alluvium and colluvium material before flattening out near the confluence with the Susquehanna River. Within this short lower section south of State Route 11, Walker Run has been manipulated and channelized to accommodate the town of Beach Haven.

III. HISTORICAL LAND USE AND EFFECTS ON PRESENT-DAY CONDITIONS

The Walker Run watershed exhibits effects of Colonial and post-Colonial (early 1700s to 1930s) land-use practices that are commonly found throughout the Ridge and Valley province. Wholesale land clearing and poor farming practices led to widespread erosion of uplands (see *Figure 4*) and massive deposition of soils in the stream valleys of the region (Cravens 1925, Costa 1975, Jacobson and Coleman 1986). As a result, pre-settlement floodplains have been buried under one to nine feet of fine sediment throughout the region.

Figure 4. Indiscriminate land clearing created massive erosion from hillsides.

Studies of the floodplain stratigraphy conducted in watersheds of the Ridge and Valley province without intensive suburban development showed three distinct stratigraphic units that developed on floodplains during at least three periods of changing hydrologic and sedimentation regimes (Jacobson and Coleman 1986). These stratigraphic units of the floodplains are believed to correspond to three general depositional periods of differing land use: pre-European settlement, intensive agricultural, and very recent (from about 1930 to the present). The floodplain units are illustrated in *Figure 5* and briefly described as:

- Pre-European settlement alluvium: light gray, fine-grained soils (clayey loam) mottled with iron and magnesium underlain by sandy, gravel, and cobble layers that are often iron-stained or weakly iron-cemented. The floodplain sediment was deposited gradually (vertical accretion) under low-energy, back-swamp conditions.

- Intensive agricultural alluvium: more uniform yellowish brown layers of fine-grained soils (silty loam). Black organic back-swamp deposits typically occur at the base of the unit. This unit often overlays the pre-settlement floodplain.

- Very recent alluvium: channel and floodplain deposits consisting of gravel and sand point-bar material, gravel bed material, and floodplain deposits under recent (after 1930) hydrologic and sediment conditions.

An awareness of the composition of the three stratigraphic units of the Ridge and Valley province floodplains helps assessors determine what happened in the past to create the current conditions and what will happen in the future if left untouched. The following narrative provides a generalized overview of historical watershed conditions and how and why Ridge and Valley streams, including Walker Run, came to be the way they are today. Understanding this process will help the reader understand the full benefits of the recommended restoration activities.

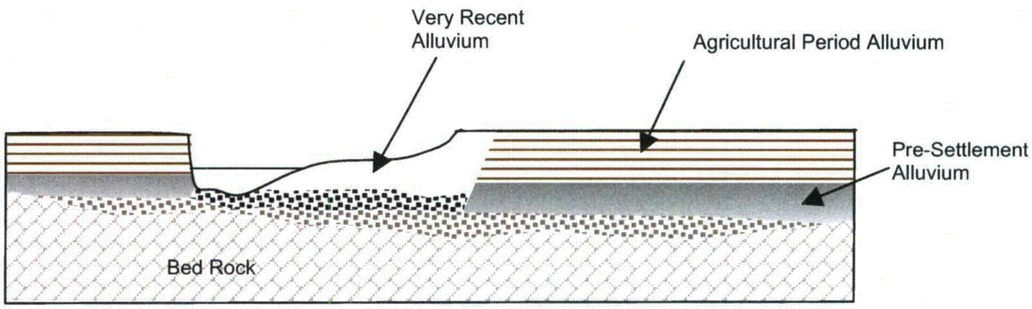


Figure 5. Cross-section of the central part of a wide floodplain in the Ridge and Valley province illustrating typical stratigraphic units. Last stage of three-stage floodplain development model (modified from Jacobson and Coleman 1986).

Pre-Settlement Conditions

Before European settlers arrived in the mid-Atlantic Region of the United States, the landscape was dominated by forests of mixed hardwoods, conifers, and a variety of woody and herbaceous flora, from mountain peaks down to the valleys and streams and rivers. In stream and river valleys, floodplains were wide and fairly flat. Floodplain soils were thin, peaty, and loamy – rich with organic material and highly porous, allowing abundant infiltration of surface water, which then percolated down to groundwater supplies. In these valleys, groundwater flowed near the floodplain surface, contributing to the base flow of the streams. (Base flow is the typical flow rate for a given stream at a particular time of year.) The floodplain surface typically rose slightly above the stream channel base flow water surface elevation.

The typical pre-settlement scenario, then, looked something like this (see *Figure 6*): relatively narrow stream channels meandered through the lower elevations of the valleys. Channel flows intersected with groundwater during times of high base flows, and recharged groundwater during drought or normal base flow conditions. Low, frequently inundated floodplains consisted of porous, well-vegetated soils. Root systems throughout the floodplain reached down to groundwater and streambed elevations, the root zone providing a large surface area for pollutant removal from groundwater and surface water. Floodplains also served as a major recharge area for surface flow because of their porous material that held and gradually infiltrated flood flows from the channel as well as overland flows.

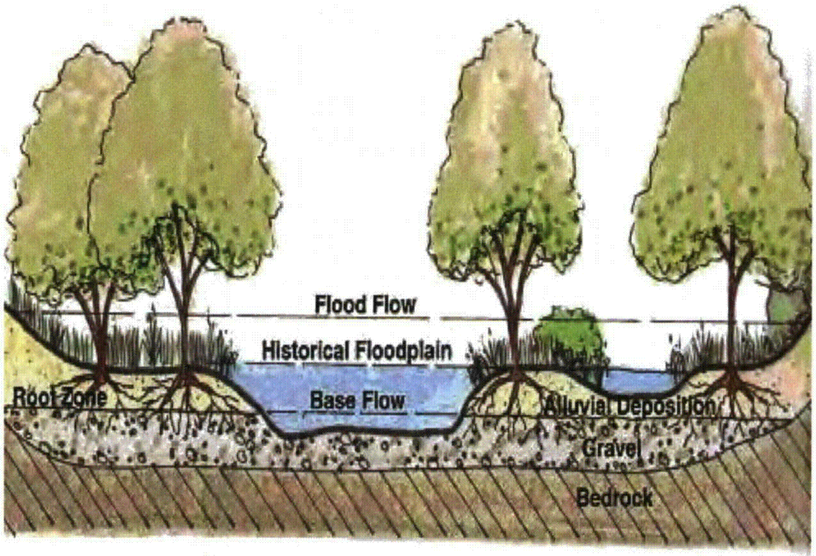
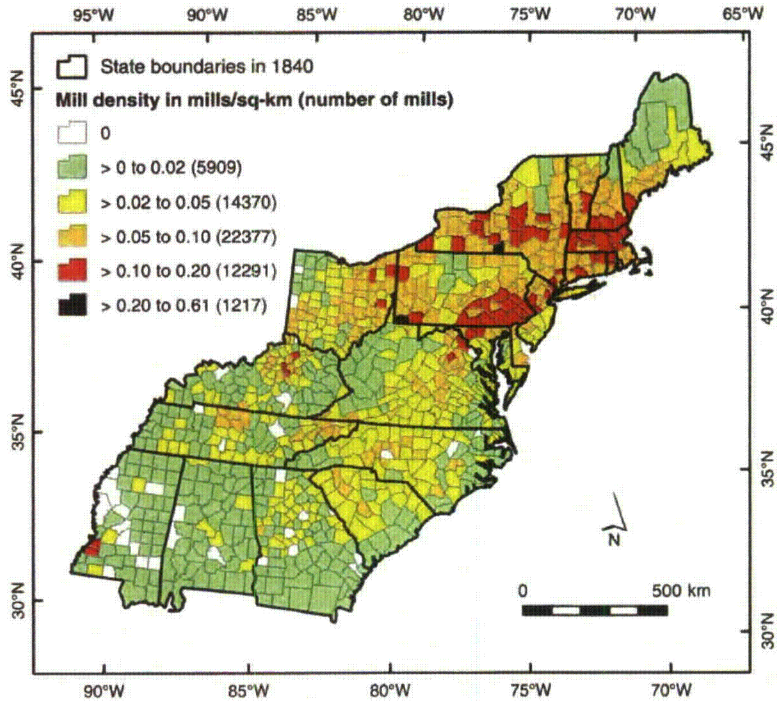


Figure 6. Stable, pre-settlement stream and floodplain systems were characterized by: a low floodplain in close contact with surface water in the stream channel, allowing for frequent inundation of the floodplain during high flows; riparian vegetation with root zones in contact with ground water that enabled groundwater denitrification through root uptake; and a channel bed composed of cobble and gravel, which helped protect the underlying bedrock from erosive flow forces.

This scenario is nature's design for a fully functioning stream system that holds its stability while helping control storm flow and purifying water supplies. The constant interaction among the various components – surface water, groundwater, soil, and vegetation – is what is required to allow a stream channel, its floodplain, and the attendant wetland pockets to provide the benefits of a fully functional system. And this, no doubt, is how stream channels and floodplains in the Walker Run watershed must have looked and functioned before European settlers arrived and began to alter the landscape.

Early Historical Impacts

During settlement and on through rapid urbanization, from the 18th century up through the first half of the 20th century, much of the vegetation disappeared through land clearing for timber, agriculture, commerce, and settlements. Massive erosion from upland slopes into stream and river valleys ensued. To make it easier for farming and other human activities, meandering stream channels were moved from the lowest elevations in the valley centers to the higher elevations at valley edges, and in the process usually were straightened. Industries during the 1600s through the early 1900s relied on streams for providing power to their facilities, which included mills, forges, furnaces, and mining operations. As a result, milldams were built on stream channels throughout the region by the thousands (see *Figure 7*). Millraces carried water from the ponds that formed upstream of the dams to the mill to turn the water wheels and generate power.



Source: Walter, Robert and Merritts, Dorothy. "Natural Streams and the Legacy of Water-Powered Mills." Science. Vol. 319. January 18, 2008. (Provided by F&M College).

Figure 7. Density of mills along eastern United States streams in 1840 by county.

Figure 8 shows the locations of historical mills along Walker Run. At least four historical mill dams existed on Walker Run. The following excerpts are from History of Luzerne County Pennsylvania, H.C. Bradsby, Editor (1893) and document the locations, owners and purpose of the historical mills as well as other activities that have led to the degradation of Walker Run.

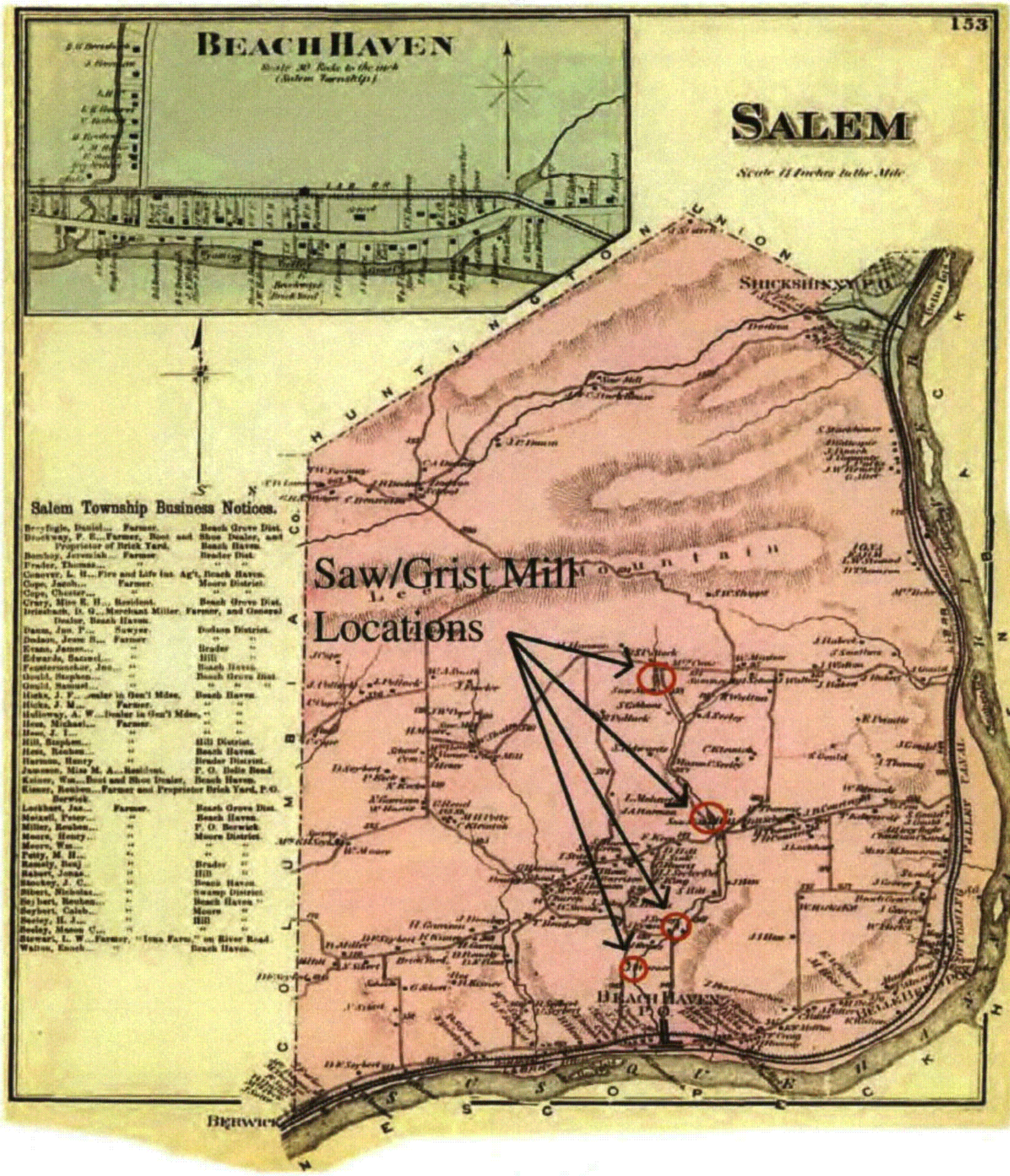
According to an 1873 map from the U.S. GenWeb Archives, Walker Run was formerly known as Mill Creek, with good reason.

"One mile below Beach Haven the Seyberts has a store, grist and sawmill, fulling-mill, [p.644] clover-mill, distillery and plaster-mill … "

"Beach Haven was plotted by and named for Josiah Beach, son of Nathan Beach, who came to the place in 1832 and built a gristmill, water power; afterward built a new mill run by water obtained from the canal company."

" … This was a noted point on the canal. The people by a little diplomacy, secured here the weight-locks as well as the regular canal-locks just below the weight-locks. The weight locks are built of massive square stone, strongly ironed together, and the office and scales-house is a substantial two-story building where is an agent on duty at all times. At the lock, just below, is a drop in the water level of thirteen feet. … "Campbell's mills were just above the town; he had clover and sawmill."

"The sawmills at the head-waters of Mill creek were built since 1840, the upper mill by S. Pollock and the one farther down the stream by Daniel Hill. There are also two sawmills at the head-waters of Seybert creek. A tannery at Beach Haven was built by Albert Hinsey in or about 1847."



Source: Pendleton, Philip E. Oley Valley Heritage – The Colonial Years: 1700-1775. Publications of the Pennsylvania German Society. Volume XXVII. 1994.

Figure 8. Historical Map of Salem Township dated 1873. Mills located on Walker Run are circled.

"Dreisbach was merchandising, his store near the creek; thinks he carried on the leading business from 1840 to 1867; then he remembers [p.647] Mrs. Anderson's store where Thomas McGraw's now stands. It was burned and they closed out in 1865 and the family went to Missouri. The building belonged to J.F. Hicks. The ground was purchased by Thomas McGraw and his present brick building erected in 1888. In the place are post office, railroad station, two hotels, two general stores, two groceries, brickyard, blacksmith and shoemaker and estimated population of 300."

In addition to the verbal documentation of substantial commercial activity from the river on up to the headwaters of "Mill Creek," the 1873 map shows four mill dam ponds above Beach Haven: one just north of Beach Haven; one near the intersection of Market Street and the connecting road between Market Street and Stone Church Road; Daniel Hill's sawmill just upstream from the intersection of Beach Grove Road and Market Street; and S. Pollock's sawmill in the headwaters, near Mingle Inn Road.

Given the plethora of mills in addition to the canal, the railroad, and numerous industries in, below, and upstream of Beach Haven, it is safe to say that Walker Run, since at least its 19th century days as Mill Creek, has borne the brunt of man's industriousness.

Behind the dams, water ponded and its flow velocity slowed down. Most of the eroded sediments and pollutants (phosphorus attaches to soil particles) that had moved into the valleys accumulated behind the dams and on the floodplains between the dams (see *Figure 9*). Over the years, the height of many dams were commonly increased and/or decreased, which was reflective of productivity. Stream channel beds and floodplains grew artificially high, perched on the fine-grained eroded materials. Elevated channel beds and floodplains were no longer closely connected to groundwater supplies; therefore, flows were composed predominantly of surface water runoff, with temperatures far exceeding that of the groundwater.

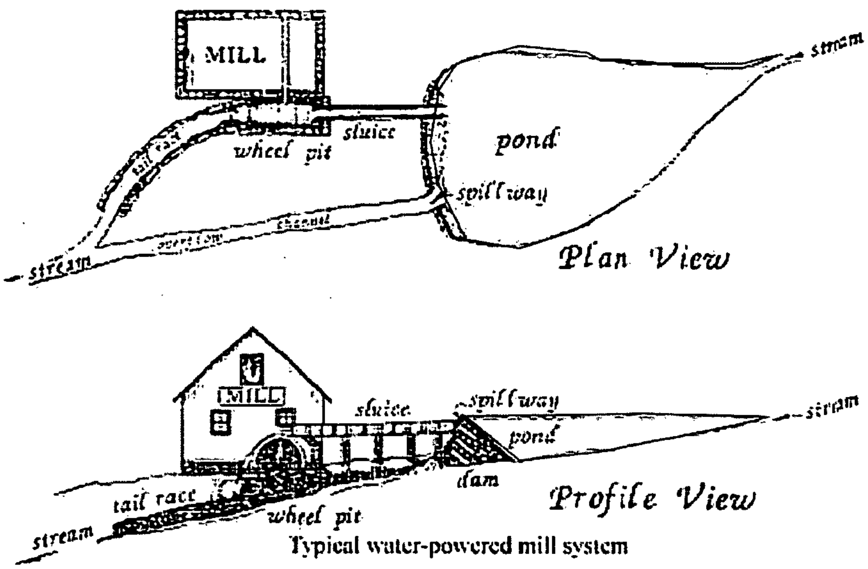


Figure 9. Plan and profile views make it easy to see how water slowed down and ponded behind dams and allowed sediments to build up behind the dams.

Vegetation changed because of the disconnection. Wetland systems were created not because of their proximity to groundwater but because they sat on dense, fine, nearly impervious sediments perched high above the streambed and groundwater. No longer could those wetland plants extend their root systems into the groundwater to remove the nitrogen compounds.

Subsequent Impacts

As dams were removed or fell into disrepair – a condition that continues today – stream channels began to work their way down through the accumulated sediments, also known as "legacy sediments," toward their historical elevations, leaving the artificially elevated floodplain behind and becoming more and more "detached" from the floodplain (see *Figure 10*). The floodplain became more accurately a "terrace", with dense, fine-grained sediments rather than porous, peaty, organic soils, and with quite different plant communities. In some cases, in order to find the path of least resistance, a stream may have been captured by a remnant millrace channel.

Channel beds have cut too deeply through the sediments to allow any but the highest flows to escape from the channel. Flow forces in the channel, therefore, are excessive and erosive, carrying stream bank sediments and attached pollutants downstream, undercutting banks and causing them to collapse, creating ongoing tree falls and resulting debris jams in waterways. Where the channels have reached pre-settlement streambed levels, flows now recharging the groundwater have higher concentrations of nitrates and other soluble pollutants.

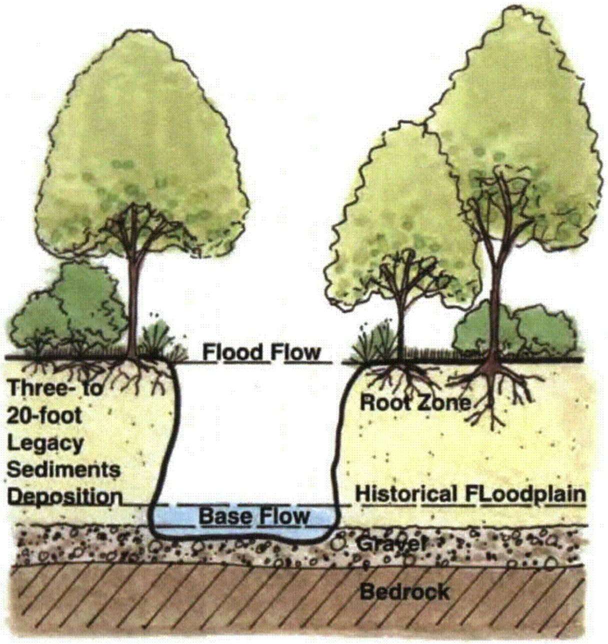


Figure 10. Stream channels are eroding or have eroded back down through sediments that collected behind mill dams, leaving their alluvial floodplains high above the current base flow water elevation, and disconnecting riparian root systems from groundwater flows. The processes of frequent floodplain inundation, relieving in-channel stresses; groundwater infiltration through porous floodplain material; and nitrogen removal from groundwater through root systems are lost under these conditions that are prevalent today throughout the Ridge and Valley Province of the United States.

The various components of a stream system can no longer interact properly. Stream banks and beds are eroding as they seek their proper elevation and location within the channel valleys. Phosphorus attached to the sediments along the banks is carried downstream with the eroded sediments. Nitrogen uptake by plants in the historical floodplain no longer occurs. Overland flows from stormwater enter the stream instead of the floodplain, where they were once filtered and percolated through the soil. Normal stream flows now have higher temperatures, because groundwater now intersects the streambed only infrequently.

The evolutionary process described above is in its early stages in many if not most Ridge and Valley streams. The process of unstable streams working their way down and horizontally toward their most stable configuration is the modern result of historical human activity and could continue for many years to come.

IV. METHODS

On March 17-18 and March 24, 2009, Landstudies performed the Stream Stability Assessment of the Walker Run watershed, in Salem Township, Luzerne County, PA. In addition to the visual assessment, five cross sections were surveyed between the Market Street bridge crossings of Walker Run, and three cross sections and bank erosion pins were installed between Beach Grove Road and Market Street. Along with these surveyed cross sections, a longitudinal profile was surveyed throughout the majority of the site in order to understand and describe the existing conditions of Walker Run. As part of the assessment, Walker Run was visually assessed by walking the entire section of Walker Run, beginning approximately 2,400 feet downstream of the Denns Road stream crossing, continuing upstream through the PPL BBNPP site, and ending approximately 3,000 feet upstream of the Beach Grove Road. See *Figure 1* for limits of visual geomorphic assessment.

The Stream Stability Assessment Procedure included performing a Level II Geomorphic Characterization and a Level III Bank Erosion Hazard Index (BEHI) assessment procedure. The Level II geomorphic characterization is determined with field measurements from specific reaches within the watershed system to classify streams into similar morphological characteristics. From this analysis, one can delineate streams into one of seven stream types. The Level II characterization process also employs a more refined criteria in order to characterize the present condition of the stream and begin to address sediment supply, stream sensitivity to disturbance, and fish habitat potential. The Level III procedure looks at the current condition of the system and allows one to make decisions about the stream's degree of departure from its operating potential, or the proper functioning condition of the system. The Level III analysis allows one to make predictions about the overall departure from normal and allows one to predict future evolutionary adjustments and responses to these disturbances.

A. STREAM TYPE CLASSIFICATION

The Rosgen Stream Type Classification method uses seven major stream types that are found naturally and are referred to as **A, B, C, D, E, F,** and **G**. Each of these stream types differs with respect to entrenchment ratio, width/depth ratio, sinuosity, streambed substrate, and slope. The single-most important parameter to be field-determined and used in the stream type classification is the bankfull stage or bankfull elevation. The bankfull stage can be described as the stage that represents the upper level of the range of channel-forming flows, which transports the bulk of the available sediment over time (Wolman and Miller, 1960). See *Figure 11* for the Key to the Rosgen Classification of Natural Rivers (Rosgen, 1996).

As discussed previously in the Existing Land Use, the Walker Run watershed overlays a land area that contains two different valley types and landscape forms. As discussed, the upper and lower portions of the watershed differ from the middle portion of the watershed, where the proposed BBNPP is to be situated, both in valley type and landform. Therefore, as part of the assessment process, a reach of the stream that displays a relatively stable or reference condition needs to be identified for use in calibrating the bankfull stage or discharge for the additional reaches assessed along Walker Run. This reference condition was identified approximately 800 feet upstream of Beach Grove Road, in the upper portion of the watershed. See *Figure 12* for the representative "stable" channel condition above Beach Grove Road.

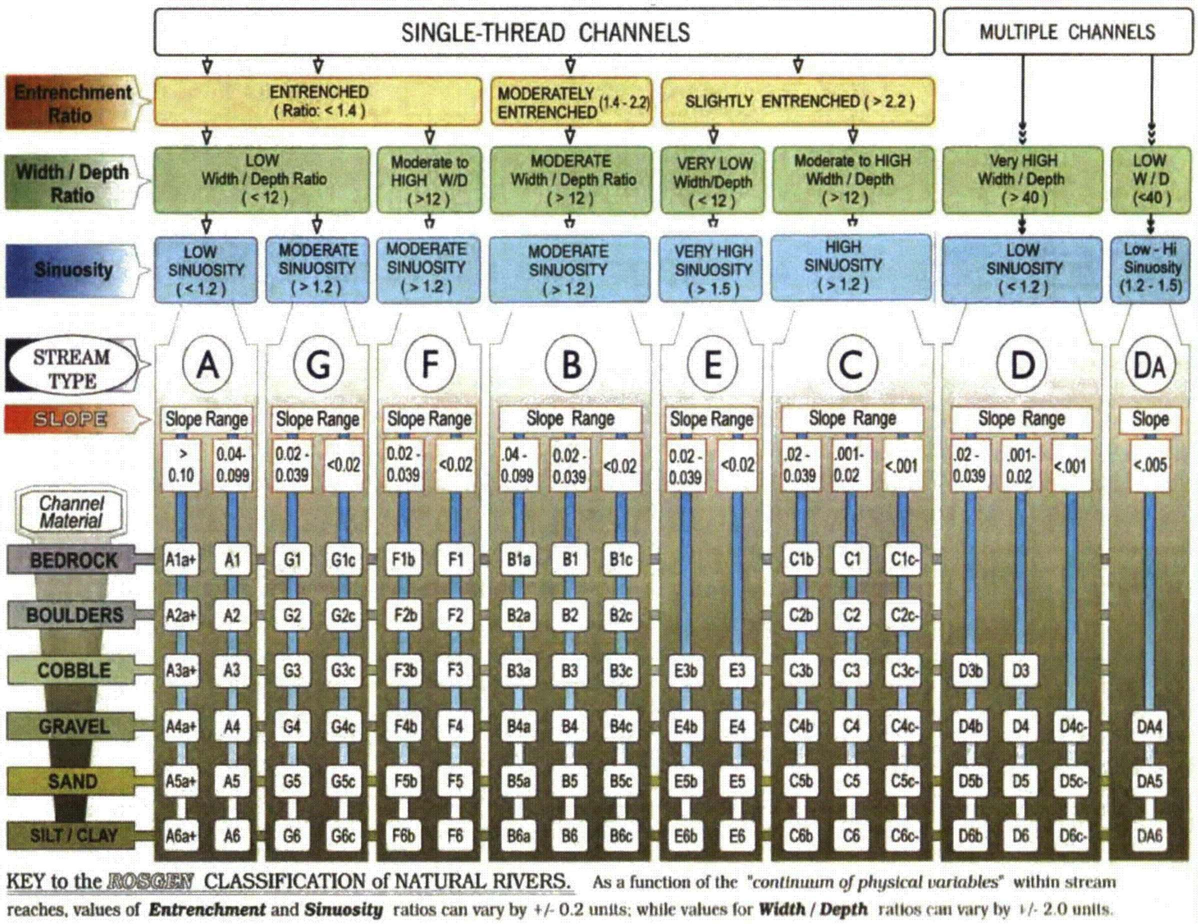


Figure 11. Key to the Rosgen Classification of Natural Rivers.

Figure 12. Reference condition for the Walker Run stability assessment would be classified as a B4c stream type in a Valley Type II. Located approximately 1,000 ft upstream of Beach Grove Road.

Stream types were classified using fluvial geomorphological principles as developed by David Rosgen in his book "Applied River Morphology." In applying this stream classification protocol, the first step was to identify the bankfull elevation in order to determine the key characteristics necessary to classify natural streams. Once the bankfull elevation was field-determined, the bankfull cross-sectional area (**A_{BKF}**), bankfull width (**w_{BKF}**), bankfull depth (**$d_{BKF} = A_{BKF}/w_{BKF}$**), maximum channel depth (**d_{MAX}** - depth of channel measured from the thalweg up to bankfull stage), and the flood-prone area width (**w_{FPA}** = channel width at 2 **d_{MAX}**) could be determined. These stream characteristics were the key parameters used to calculate the stream entrenchment ratio (**w_{FPA} / w_{BKF}**) and the stream width/depth ratio (**w_{BKF}/d_{BKF}**) and were used to classify stream types. Other useful information used in the stream type classification included an estimate of the mean streambed particle size. Once this information was collected, the stream reach could then be classified by these specific morphological characteristics.

B. Bank Erosion Hazard Index (BEHI) Rating

The Level III Bank Erodibility Hazard Rating goes beyond the stream system classification in order to define the current state of the stream as related to stability. Parameters that are evaluated in the field to determine the current condition and predict trends of stability include the influence of the riparian vegetation, sediment supply, flow regime, debris occurrence, depositional features, channel bed substrate and stability, and bank erodibility to predict both lateral and vertical degradation. Predictions are made from the current stream condition to determine if the disturbed channel is aggrading or degrading.

Bank erosion rates are predicted using the Bank Erodibility Hazard Index (BEHI) methodology. The BEHI is calculated by measuring the study bank properties such as the exposed bank height, bank height ratio, stratification of materials, root depth, root density, and bank angle. The BEHI is used in conjunction with the Near Bank Shear Stress computation to predict typical erosion rates. Vertical stability within the BEHI analysis is evaluated using the Bank Height Ratio (BHR) methodology. This ratio provides useful information on the extent of vertical confinement or entrenchment that is imposed in the stream corridor and essentially on the streambed. The higher the BHR or the more confined a stream channel becomes, the greater the potential for erosive conditions on the streambed and banks due to the confinement of higher flow events being contained within the channel. Any value greater than 2.0 would be considered highly incised and typically unstable.

V. FINDINGS

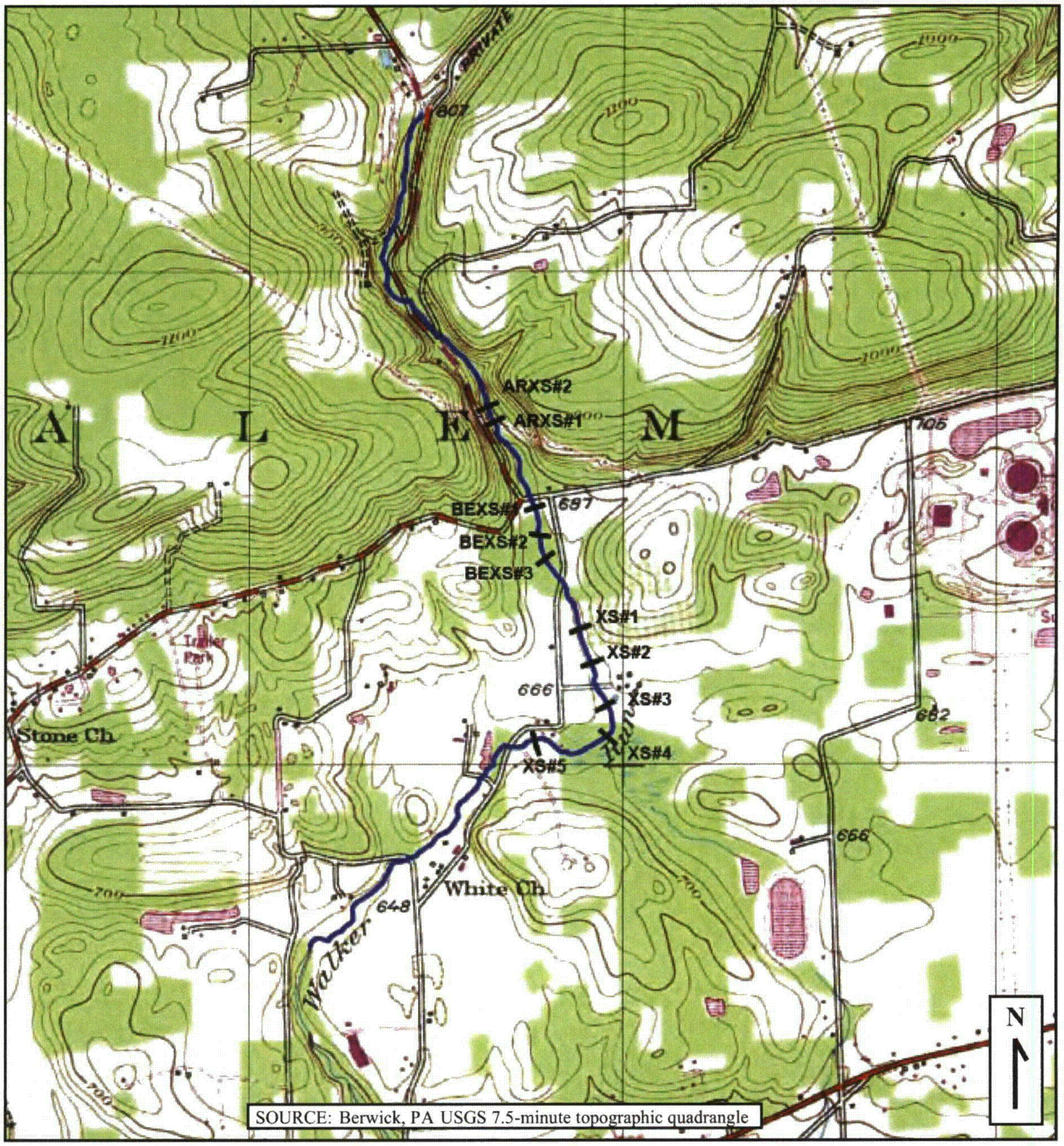
A. STREAM VISUAL ASSESSMENT

The stream visual assessment was completed in conjunction with a number of geomorphic surveys that were completed along the Walker Run stream system within the BBNPP site. Within this property, eight geomorphic cross sections were laser-level surveyed to accurately represent typical existing conditions throughout the project reach. In addition to the cross sections surveyed, four longitudinal profiles were surveyed along with photo-documentation of each of the cross sections. Also, as part of the geomorphic surveys, two assessment reach cross sections were surveyed, along with a longitudinal profile and a Wolman pebble count to characterize a representative stable reach along Walker Run. See *Figure 13* for location of surveyed cross sections. The geomorphic surveys and photo-documentation are included in Appendix A.

The stream visual assessment began approximately 2,400 feet downstream of Denns Road where Walker Run transitions from the lower portion of the watershed up into the middle portion of the watershed. This transition zone in the downstream direction is marked by an increase in valley slope and a change in the valley type. The middle portion of the watershed is characterized by a wide flat valley floor with abandoned stream terraces, whereas the lower portion of the watershed is characterized by of a steeper and more confined colluvial valley.

At the lower limits of the visual assessment where the valley types transitioned, there is a remnant building foundation along the right floodplain area that may have been the downstream-most milldam identified on the historical map in *Figure 8*. Within this lower reach of Walker Run, the stream is somewhat entrenched and undergoing some minor lateral adjustment. It appears that the vertical degradation occurring in the system's unstable condition is causing the larger gravels and cobble of the streambed to be mobilized for short distances and re-deposited downstream. The movement of the bed material is promoting ongoing lateral adjustment.

Farther upstream, a private farm road crossing over Walker Run consists of a 10-foot span concrete bridge with a vertical opening of approximately 24-36 inches. See *Figure 14* for private bridge crossing.



Legend

- Assessment Reach
- Cross-Section Location

Scale

1 inch equals 2000 feet

500 0 1000 2000

FIGURE 13. Geomorphic Survey Cross-Section Locations along Walker Run
PPL Bell Bend Nuclear Power Plant, SalemTownship, Luzerne County, PA

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Figure 14. Private farm road crossing downstream of Denns Road.

The stream in and around the private crossing is in a state of streambed aggradation on the upstream side and lateral adjustment and vertical degradation on the downstream side. The downstream degradation is a result of both lateral and vertical adjustments moving headward from the downstream direction. Above the private road crossing, channel aggradation is evident, as seen in *Figure 15.* The streambed aggradation is a result of the larger gravels and cobbles transported from the upstream-incised reach depositing there because they cannot be transported through the private crossing.

Figure 15. Picture of Walker Run looking upstream from private road bridge deck. Note streambed substrate deposition immediately upstream of bridge crossing.

The aggradation process flattens out the stream slope and creates a backwater condition that further reduces the energy available to move the bedload and prevents additional material from being transported downstream. The process of bedload deposition in this area is also promoting lateral adjustments in order to accommodate the flows and sediment from upstream as material is being deposited and reducing conveyance in the channel. If the bridge is removed or fails, there will be significant adjustments in the longitudinal profile and the planform in both the upstream and downstream directions.

The backwater condition created by the local aggradation near the private bridge crossing extends approximately one thousand feet upstream. The backwater conditions of this reach create a long, flat pool with minimal vegetative cover that does not lend itself to a diverse macro-invertebrate community. In addition, the kind of streambed substrate required for a diverse benthic macro-invertebrate community is minimal in this reach. The majority of the streambed substrate consists of sands and silts. See *Figure 16* for typical backwater conditions. Throughout this reach, the channel is somewhat entrenched and, during higher flow events, the existing streambed material is being scoured because of the incision of the channel and is being mobilized and re-deposited at the downstream bridge crossing. This scour action also minimizes the potential for long-term stability and reduces the high-quality biological habitat.

This section of Walker Run appears to have been straightened. This can be seen where the old abandoned oxbow meander bends that once meandered across and down valley have now converted into emergent wetland areas since the channelization of Walker Run within this reach.

Figure 16. Backwater condition extending upstream for approximately 1,000 from private road crossing. Somewhat incised C5or F5 stream type.

Upstream, north of Denns Road, Walker Run passes behind a number of residential homes. Within this reach as well, the channel appears to have been straightened. There is also an earthen berm that runs immediately adjacent to Walker Run along the right streambank and floodplain. This may be the remnant features of what may have been a milldam identified on the historical mapping as seen in *Figure 8*. See *Figure 17* for earthen berm adjacent to Walker Run

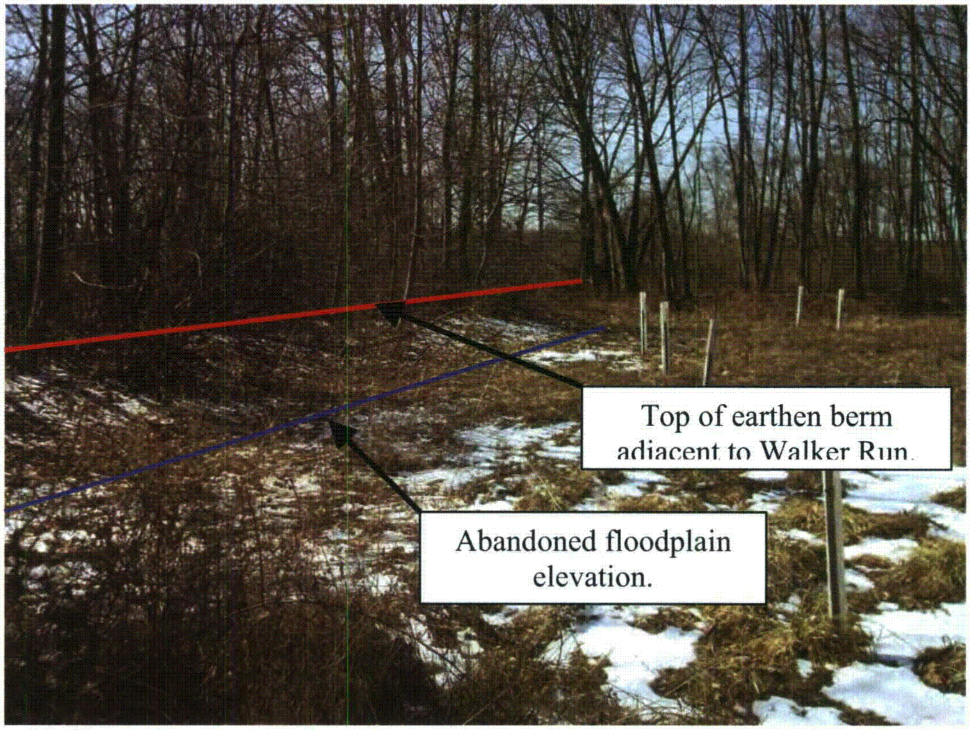

Figure 17. Three-foot earthen berm located immediately adjacent to Walker Run beginning approximately 100 feet upstream of Denns Road and extends another 500 feet upstream. Walker Run is located on the opposite side of earthen berm.

Within this reach of Walker Run, where the channel runs parallel with earthen berm, the channel is somewhat entrenched, straightened, and/or channelized and would probably be considered an incised C5/E5 stream type that is losing its connection with a functional floodplain. It may even be considered and entrenched G5/F5 stream type based on the elevation of the bankfull stage. The existing instability of the reach is compounded by the fact that the three-foot earthen berm prevents flood flows from accessing the right floodplain. Additionally, the streambed substrate is mainly composed of silts and sands; very little gravel is present in Walker Run throughout this reach, which extends upstream to the Market Street bridge. The stream channel is fairly straight throughout this reach, probably as a result of ditching and channelization to drain wetlands that were present to accommodate the agricultural activities adjacent to Walker Run. Again, within this reach, gravel substrate was very sparse and consisted of less than five percent of this reach; the majority of the reach consisted of silts and sands.

As discussed previously as part of the visual assessment of Walker Run, additional geomorphic assessments were performed along the reach of Walker Run between the Market Street bridge crossings. Within this section of Walker Run, five geomorphic cross sections were surveyed, along with a longitudinal profile throughout the majority of the reach. See *Figure 13* for a location map of surveyed cross-sections along Walker Run. The results of the geomorphic surveys between the Market Street bridges are summarized in Table 2.

Table 2. Geomorphic Characteristics of Surveyed Cross Sections.

Cross Section Identification	Cross Section #1	Cross Section #2	Cross Section #3	Cross Section #4 (Run)	Cross Section #5
Stream Type	F5/IncisedG5	F5/IncisedG5	F5/IncisedG5	F5/IncisedG5	F5
Cross Sectional Area (sf)	8.8	9.4	8.7	14.2	8.5
Width (ft)	8.2	9.1 9.7		12.0	10.4
Mean Depth (ft)	1.1	1.0	0.9	1.2	0.8
Entrenchment Ratio	1.5	1.2 1.2		NA	1.2
Width/Depth Ratio	7.6	8.9	10.9	NA	12.6
Discharge (cfs)	25.0	26.1 23.4		NA	21.1
Visual D50 (mm)	2	2	2	2	2
Average Slope (ft/ft)	0.0035	0.0035 0.00	35	0.0035	0.0035
Bank Height Ratio (BHR)	2.4	2.3	2.8	2.2	2.8

Based on the data collected at these five cross sections, the Walker Run stream throughout the BBNPP site would be considered an entrenched and degrading incised F5 or G5 stream type. This is based on calibrating the bankfull discharge at the assessment-reach and applying this discharge within the cross sections surveyed downstream of the assessment reach. This was done because of the high degree of difficulty in identifying a bankfull feature within the existing entrenched stream system.

As the Walker Run stream conditions are described in the upcoming narrative, the five geomorphic cross sections that were surveyed within the BBNPP site will be identified in order to help clarify the context within which the current channel condition is being described.

Continuing upstream from the lower Market Street bridge crossing, Walker Run undergoes varying changes in morphology, such as increased bank heights, changes in entrenchment, particle size distribution of streambed substrate, and profile adjustments. In this lower section of Walker Run, consisting of approximately 1,000 feet, Walker Run would be considered an incised and entrenched F4/F5 stream system. The cross section surveyed along this reach is identified as Cross Section #5 and shown in *Figure 18*. This reach is located within an existing meadow area and appears to have been used for historical agricultural practices, such as cattle grazing. The streambed is planar with very little change in stream features, i.e. riffles, runs, pools, and glides. The majority of the reach consists of long flat pools with short riffles. However, within this reach the streambed substrate consists of gravels and cobbles for the majority of the reach, although there are some sections along this reach where the streambed consists of only silts and sands. See *Figure 18* for typical conditions within this lower reach.

Figure 18. Typical incised conditions within lower reach of Walker Run. Surveyed cross section #5 showing planar streambed and long flat pools.

Continuing upstream, Walker Run passes through a 36-inch diameter corrugated steel pipe culvert. A private farm road crosses Walker Run at this culvert. The farm road is an elevated feature in the valley and acts like a earthen dam across the valley, preventing proper conveyance of flood flows and sediment from being transported down valley.

Upstream of the culvert, Walker Run continues to become significantly entrenched and incised. The stream flows through a mature stand of trees for approximately 600 feet before it enters into an open meadow setting and agricultural fields. The forested section has degraded vertically to match the elevation of the downstream culvert; however, an existing beaver dam is controlling the upper section of this forested reach. You will notice from the longitudinal profile, included in Appendix A, the streambed maintains a fairly consistent average slope through the beaver dam; however, the beaver dam significantly affects the water surface elevation. The streambanks below the beaver dam range from two to four feet high and are composed of fine alluvial silts and sandy material. See *Figure 19* for typical conditions within the forested reach where a cross section was surveyed and *Figure 20* for the existing beaver dam showing the three-foot elevated water surface.

Figure 19. Typical conditions within forested section of Walker Run where Cross Section #4 was surveyed.

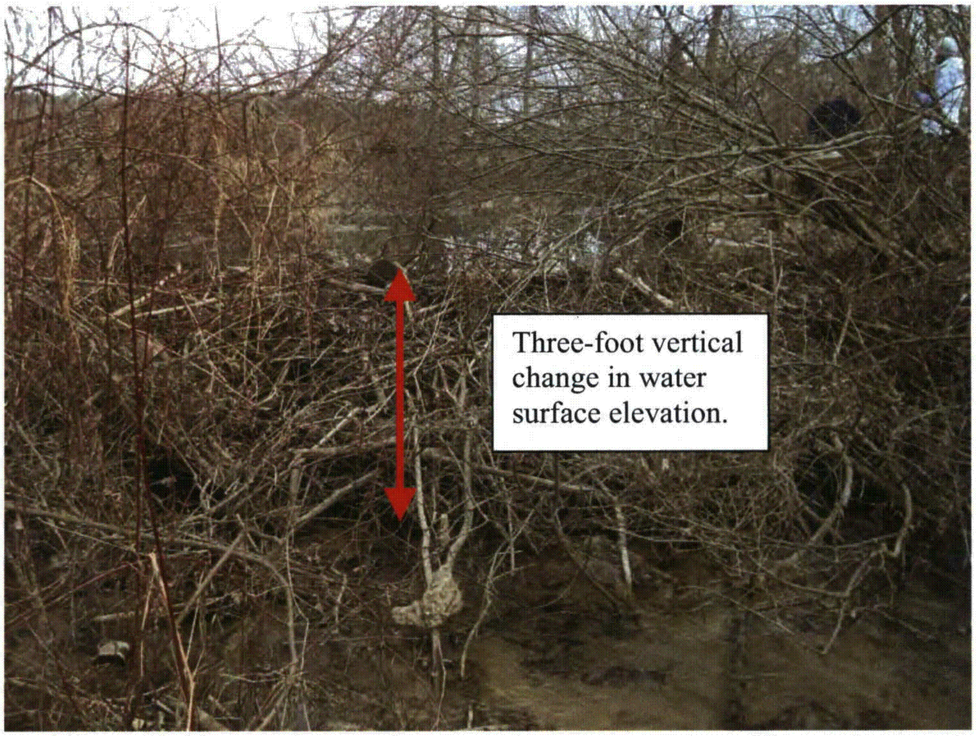

Figure 20. Existing beaver dam near the upstream edge of forested area.

Just outside the forested area immediately upstream of the existing beaver dam, the stream would be considered an E5/E6 stream type with a fairly well attached floodplain; however, this is so only because of the existing beaver dam at the edge of the forested area. When the beaver dam fails and

is breached during a significant flow event, the stream system will vertically adjust and would then be classified as a G5/F5 stream type.

The beaver dam is naturally elevating the water surface throughout the middle portion of the site. This, in turn, is reducing the average water surface slope and therefore reducing the shear stress within the channel and reducing the potential for vertical channel degradation. However, if – and, more importantly, when – the beaver dam is washed away during a significant rain event, the average stream slope will again steepen and shear stresses will exceed the threshold of mobility, which will lead to both vertical and lateral degradation. All the sediment now being stored upstream of the beaver dam will be flushed downstream, which will compound the existing instabilities in the downstream incised and entrenched reach and will lead to excessive sedimentation in the channel and the degradation of the existing biological community.

Beginning north of the existing farm lane access on the BBNPP site, above the backwater condition created by the existing beaver, Walker Run becomes significantly entrenched and incised. As part of the assessment, two geomorphic cross sections were surveyed within this reach to characterize the existing conditions. See *Figure 21* for typical conditions along this reach of Walker Run, upstream of the farm access road.

Figure 21. Typical conditions upstream of farm road with four to five foot streambanks.

Even though the streambanks appear to be fairly well vegetated, the stream channel has lost its connection with a functional floodplain, which leads to further vertical and lateral adjustment. Because of the high entrenchment conditions within this reach, habitat conditions are not ideal for sustaining a diverse biological habitat and macro-invertebrate community. Additionally, the streambed substrate consists mainly of silts and sands with the occasional large cobble and or boulder, most likely from being exposed as a result of being moved to the eastern fringe of the valley.

Additionally, throughout this reach, Walker Run has been channelized and historically been moved to the eastern edge of the valley in order to maximize the agricultural fields adjacent to Walker Run. This in effect has reduced stream lengths and therefore steepened stream slopes. This adjustment in profile and planform has had a significant affect on the current vertical and incised conditions within the reach.

Continuing upstream near the Market Street bridge crossing, Walker Run becomes more incised and entrenched. The channel has been pinched up against the eastern valley slope. There are short, steep riffles where the bed appears to be perched on the larger colluvial material at the base of the valley slope that was exposed as a result of the historical channelization. This perched streambed condition creates a long backwater condition immediately downstream of the Market Street bridge crossing. This reach consists of an incised and degraded F5 stream type. The streambed substrate consists of silts and sands, most likely as a result of the flattened stream slope leading to sediment deposition. See *Figure 22* for incised F5 stream system consisting of a long flat backwater condition and planar streambed.

Figure 22. Photograph looking downstream near the upstream Market Street bridge crossing. Incised F5 stream type along Walker Run consisting of long flat pool.

North of the Market Street bridge, Walker Run is pinched up against the roadway side slope. The channel then turns to the left and heads across the valley bottom to the western fringe of the valley. Where Walker Run turns to the west, there is a short, steep riffle flowing across larger colluvial material. This large colluvial material does not fit in with the rest of the geologic landscape and stream condition and appears to be remnants of a past historical activity, such as a roadway improvement project near the bridge crossing. It may also be from local bank armoring of the channel as it traverses the valley toward the existing bridge.

Throughout the entire reach from the Market Street to the Beach Grove Road crossing, Walker Run is significantly incised and entrenched. The existing streambanks range in height from three to five feet and are composed of fines silts and sands. The existing valley bottom consists of a fairly mature stand of trees with minimal rooting depths, as can be seen in *Figures 23 and 24*. This condition of increased bank heights in conjunction with fine alluvial streambanks and elevated root systems does not provide adequate protection for long-term stream stability during higher flow events and leads to accelerated streambank erosion. Trees are being undermined and are falling into the stream, promoting streambed scour. Throughout this reach, the majority of the streambed consists of fine alluvial silts and sands, most likely a result of the ongoing streambank erosion. However, in the upper 200 feet immediately downstream of the Beach Grove Road crossing, the streambed consists of small to medium sized gravels. See *Figures 23 and 24* for typical conditions throughout this reach.

Figure 23. Typical condition of eroding streambanks upstream of the Market Street bridge.

Figure 24. Typical stream conditions near bank erosion cross-section #2 with high eroding streambanks.

Within the reach between the Beach Grove Road and the Market Street bridge crossing, three cross sections were surveyed and additional geomorphic data were collected to assess the bank erosion potential within this reach, such as bank angle, rooting depths, root density, bank heights, bank material, and to determine if there is any surface protection along the banks to evaluate the Bank Erosion Hazard Index rating. Along with the surveyed cross section, the Near-Bank Shear Stress was evaluated to predict long-term stability and the potential for lateral adjustment. The information associated with the Bank Erosion Hazard Index Rating and long-term erosion potential is discussed in the next section.

Upstream of the Beach Grove Road crossing, Walker Run flows through a different valley form and landscape. The valley slope becomes significantly steeper and the valley type is more confined with steeper side slopes. From the bridge crossing at Beach Grove Road, the upstream section of Walker Run would be considered to be in the upper watershed, as previously discussed. This portion of the watershed appears to be in a somewhat more stable condition; the channel appears to be fairly well connected to a floodplain or flood prone area. There are, within this upper section of Walker Run, reaches that would be considered braided with minor lateral extension. As a result of this braided condition, sheer stress energies are minimized and therefore this reach does not provide a significant source of larger colluvial material to the downstream sections of Walker Run.

Approximately 1,000 feet upstream of the Beach Grove Road is the assessment reach where the bankfull stage was calibrated for use to estimate the bankfull stage in the geomorphic cross sections surveyed downstream on the PPL BBNPP site. See *Figures 25 and 26* for the two assessment reach cross sections surveyed. The geomorphic surveys are included in Appendix A. At this location two cross sections were surveyed along with a 320-foot longitudinal profile. A Wolman pebble count was performed in order to estimate channel roughness. This information was used to determine channel mobility and sediment transport criteria for the bankfull calibration procedure. Table 3 summarizes

the bankfull characteristics of the assessment reach. From this analysis of the assessment reach condition, the bank full discharge was determined to range between 19.3 and 29.3 cubic feet per second (cfs). This bankfull discharge was then used to estimate the bankfull stage or elevation within the eight cross sections surveyed on the BBNPP site to further classify the existing conditions on-site. The bankfull elevation could not be visually identified in the eight geomorphic cross sections because of the existing entrenchment of the system.

Table 3. Geomorphic Characteristics for Assessment Reach Cross Sections

Cross Section Identification	***Assessment Cross Section #1***	***Assessment Cross Section #2***
Stream Type	B4	B4
Cross Sectional Area (sf)	12.3	9.8
Width (ft)	18.3	17.4
Mean Depth (ft)	0.7	0.6
Entrenchment Ratio	1.9	2.0
Width/Depth Ratio	27.8	31.0
Discharge (cfs)	29.3	19.3
D50 (mm)	57	57
Average Slope (ft/ft)	0.017	0.017

Figure 25. Assessment reach Cross Section #1 looking upstream.

Figure 26. Assessments reach Cross Section #2, looking upstream.

B. Bank Erosion Hazard Index Rating Assessment

The Bank Erosion Hazard Index Rating was completed by conducting laser level surveys of three cross sections on the reach of Walker Run from Beach Grove Road to the Market Street bridge crossing. A longitudinal profile was surveyed through the reach where the cross section was surveyed to use in calculating the Near Bank Stress. Bank pins were installed at each survey location to facilitate future measurement of actual erosion rates. From these surveyed cross sections (Geomorphic Surveys included in Appendix A), stream types were identified for each cross section and the bankfull stage was estimated. From this analysis, a bank erosion potential was determined based on several characteristics of the study bank, including bank height, bank angle, root density and root depth, bank materials, and surface protection. The geomorphic characteristics of the surveyed cross sections are summarized in Table 4 and the geomorphic data and photo-documentation are included in Appendix A.

Table 4. Geomorphic Characteristics of Bank Erosion Cross Sections.

Cross Section Identification	***Bank Erosion Cross Section #1***	***Bank Erosion Cross Section #2***	***Bank Erosion Cross Section #3 (Pool)***
Stream Type	F4/Incised B4	F5	F Stream Type
Cross Sectional Area (sf)	6.0	7.7	10.1
Width (ft)	8.9	11.7	12.9
Mean Depth (ft)	0.7	0.7	NA
Entrenchment Ratio	1.5	1.21	1.2
Width/Depth Ratio	13.0	17.8	NA
Discharge (cfs)	20.1	23.8	19.3-29.3
Visual D50 (mm)	20	8	8
Average Slope (ft/ft)	0.007	0.008	0.00035
Bank Height Ratio (BHR)	2.4	2.3	2.6

In addition to the bank erosion index, near bank shear stress calculations were determined for the near bank region of the individual cross sections. This calculation is related to the distribution of streamflows and velocity gradients in the near bank region, which can be defined as the region that is one-third the portion of the channel cross section nearest the study bank. The shear stress methodology used to calculate the shear stress in the near bank region used the ratio of the shear stress in the near bank region to that of the average shear stress of the cross section. From this analysis, a shear stress rating was determined and used in conjunction with the streambank erodibility rating to predict erosion rates.

Based on the two variables determined in this assessment, the predicted erosion rates were estimated by using the United States Forest Service work that Dave Rosgen developed in Yellowstone National Park, CO (Rosgen, 1996). These predictions are for estimation purposes only. See Appendix A for photo-documentation of the individual cross sections surveyed and Bank Erosion Hazard Index Ratings. In order to truly quantify streambank erosion rates, surveys of the existing monumented cross sections need to be undertaken at some future time to represent true conditions within this watershed.

Based on the results of the Bank Erodibility Rating and the Shear Stress calculation in the near bank region, erosion rates are predicted using the Rosgen's data, as noted above. The results for this reach of Walker Run are summarized in Table 5.

Table 5. Bank Erosion Hazard Index (BEHI) Rating Scores

Cross Section Identification	***BEHI Rating***	***Near Bank Shear Stress***	***Bank Height Ratio (BHR)***	***Predicted Annual Erosion Rate***
1	High	Very High	2.2	1.75
2	High	Low	2.3	0.45
3	High	Very High	2.6	1.75

Based on the BEHI analysis of the three cross sections, this reach of Walker Run is considered fairly unstable with highly active erosion rates. From the data developed by Dave Rosgen, it is estimated that there will be approximately 0.45-1.75 feet of erosion along these streambanks per year, with an average of 1.15 feet. Based on the visual assessment and the assumption that only one streambank is actively eroding, we can estimate the average sediment load being generated from streambank erosion along these systems. The reach of Walker Run that was evaluated using the BEHI information consists of approximately 1,200 feet of stream channel with average bank heights in the neighborhood of four feet. Based on these assumptions, we can estimate a total annual sediment load of approximately 450 tons of sediment being eroded downstream annually from this reach of Walker Run. This equals approximately 200 cubic yards of sediment or approximately 20 tri-axle truckloads of sediment per year. It is believed that this quantity is an under-estimate of the sediment load being generated from these reaches because the streambanks are composed of easily erodible, fine alluvial sediments and the predicted erosion rates relationships are based on a data set from the Colorado Rockies, which is more typically characterized by coarser gravels and cobbles. This assumption is based on the energy required to move a particle of a given size and that less shear stress can mobilize smaller particles such as silts and sands similar to the sediments identified within the project site.

All that being identified, the contribution of sediment from the existing streambanks further exacerbates the instability of the system through local depositional processes and the development of point bars that eventually will lead to further lateral migration and streambank erosion. Only after a very long time (geologic time) will enough erosion have occurred to widen the floodplain enough to

reduce the shear stress in the channel for all flows and thereby allow the formation of a self-sustaining channel that can transport the load from the watershed without aggrading and/or degrading.

Erosion from the upper reach of Walker Run is contributing an excessive sediment load to the downstream project site. Sediments eroded from the upstream reach are transported downstream and deposited behind the beaver dam at the lower end of the project reach, which is degrading water quality and habitat conditions within the reach. This depositional process is also apparent upstream of the Market Street bridge crossing, as the majority of the channel is composed of silts and sands. .

VI. CONCLUSIONS

Currently, Walker Run flows through a watershed with a history of both early industrial activities, such as saw and gristmills, and more recent agricultural activities that have manipulated the land and valley forms within the watershed. The existing degradation within the middle portion of the watershed probably is the compounded result of anthropogenic influences – land clearing that allowed sediments to erode and settle into valley bottoms in conjunction with the construction of numerous mill dams, ditching to drain wetlands, and channel straightening and relocation to maximize agricultural land and facilitate roadway development.

There were two methodologies that were used to determine existing channel conditions along Walker Run. The first was the geomorphic characterization of Walker Run through both a visual assessment and through geomorphic surveys to classify the existing streams. Based on this classification system and the visual assessment within the middle portion of Walker Run, Walker Run would be considered to be in a significantly degraded condition or transition state. Additionally, the Level III Bank Erosion Hazard Index (BEHI) Rating was used to predict adjustment trends of Walker Run within this reach and to predict future trends of the system and long-term bed and bank degradation. Therefore, based on these two methodologies, Walker Run appears to be in a phase of both vertical and lateral adjustment, which will be visually evidenced through the continued actions of streambank erosion.

Even though there appears to be moderate to sufficient vegetation along the Walker Run stream corridor to protect against streambank erosion, the streambanks within these reaches are composed of fine alluvial sediments that are very easily erodible and will continually be undermined through erosive processes. This is due to the somewhat incised and entrenched conditions and the inability of higher flow rates to access a functional floodplain in order to minimize shear stress in and along the streambed and streambanks. These erosive processes will cause trees to be undercut and fall into Walker Run, further promoting streambank erosion and lateral extension of Walker Run. This ongoing lateral extension and streambank erosion process was visually identified in the lower reach of the BBNPP project site and in the reach between Beach Grove Road and the Market Street bridges.

Also, as the sediments move downstream, they will be trapped behind the existing beaver dam in the lower portion of the BBNPP project site. These sediments will continue to aggrade within this reach of Walker Run (approximately 300 feet) and further decrease the biological habitat and community in and along this reach. When enough sediment fills the channel behind the beaver dam and degrades the beaver habitat, the beaver will move to another area within Walker Run or to an adjacent watershed. When this process occurs, the existing beaver dam will eventually fail and will release all the sediments that had deposited behind it. This process of channel deposition and degradation is similar to the effects of the historical milldams as discussed in Section III. When the dam breaches, the channel will cut back down through the sediments deposited behind the beaver dam and will promote significant channel instabilities in both the upstream and downstream direction.

It is the conclusion that this middle portion of Walker Run has been manipulated historically, which has led to the current condition along Walker Run. The Walker Run system is somewhat to significantly entrenched and has degraded from the lower end of the visual assessment (beginning 2,400 feet downstream of Denns Road) up to the Beach Grove Road crossing. The majority of the channel is somewhat to significantly incised and is losing or has lost its connection with a functional floodplain. The channel appears to have been straightened in numerous locations, (south of Denns Road just north of Denns Road, and within the project site), and there are numerous reaches within

Walker Run where streambank erosion is significantly undermining the existing vegetation, which leads to further streambank erosion.

Based on the visual assessment of Walker Run, there are numerous locations throughout the watershed where stream restoration activities may provide an alternative to the impacts associated with the BBNPP project site. Restoration activities would not only provide mitigation for the proposed impacts, but also may assist in improving water quality and therefore improve biological diversity within the stream corridor. Additional benefits would include increased groundwater infiltration, improved flood flow conveyance, wetland creation, and flora and fauna habitat improvements.

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APPENDIX A

Geomorphic Plots of Channel Cross Sections and Longitudinal Profiles