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Restoration Plan for Plum Run Watershed Chester County, Pennsylvania February 2008

Prepared for:

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RED Streams BLUE
A BVA PROGRAM

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1.0 INTRODUCTION

"Red Streams Blue" is a program Brandywine Valley Association has developed to focus on improving the water quality of impaired stream sections throughout the Brandywine Watershed. Plum Run is a "red" stream due to excessive sediment and corresponding siltation in the watershed. The PA Department of Environmental Protection includes all but one small unnamed tributary to Plum Run in its 303d list of impaired stream reaches (DEP 2004). The unnamed tributary that is listed as un-impaired is located primarily in West Chester University's Gordon Natural Area and is a tributary to the East Branch of Plum Run.

The water quality in Plum Run varies dramatically between the East and West Branch (DiFrederico 2007). While both originating from an urban landscape, the East Branch travels through a greater percentage of forested area than the West Branch and has correspondingly better water quality. DiFrederico recommends focused restoration on the West Branch as there is a greater margin for improvement of water quality and potentially a greater effect on downstream water quality from projects in that area.

Here, we present a restoration plan for Plum Run Watershed to address specific areas of impairment. With a clear plan for restoration, we may attain the greatest value from investments in the watershed.

In the environmental and biological fields of study, sources and causes of pollution in a watershed (leading to impairment) are typically categorized into two broadly defined categories known as Point Source Pollution and Non-point Source Pollution. The terms "point source pollution and non-point source pollution" refer not to a specific polluting substance or practice, but rather describe the means by which a pollutant is introduced.

Point source pollution is most often associated with industries or municipalities that discharge wastewater to natural waters through a pipe or ditch. Point sources of pollution can be measured and treated, therefore discharges of wastewater in the United States are regulated under the provisions of the Clean Water Act and must obtain discharge permits issued under the National Pollutant Discharge Elimination System (NPDES). An NPDES permit requires the discharger to meet certain technology-based effluent limits and perform effluent monitoring. Raw sewage piped to a stream could be broadly referred to as point source pollution.

Unlike point sources, non-point sources of pollution occur over a wide area and are usually associated with large-scale land activities such as agriculture, livestock grazing, mining, logging and development of impervious surfaces resulting in increased amounts of often-polluted stormwater runoff. Since there is not one specific point of discharge, non-point source pollution is difficult to measure, regulate and treat because of the nature of the activities that cause it and the large-scale areas associated with generating the stormwater runoff. Non-point source pollution includes stormwater runoff that contains harmful substances. Types of non-point source pollution common to agricultural areas include sedimentation from crop fields and nutrient runoff from barnyard wastes and livestock loafing in waterways. The lack or the removal of vital habitat components (such as the destruction of forested riparian corridors) is also a cause of impairment.

1.1 Land Development Concerns

The primary problem resulting from increased land development is the increase in stormwater runoff from impervious surfaces such as roofs, parking lots, roads and driveways. The increase in stormwater volumes and velocities results in accelerated erosion and sedimentation, while thermal and chemical pollution from roads and large parking lots further degrade water quality. The increased sediment can lead to other problems including alterations in the natural configuration of the channel, loss of stream meanders, decreased diversity of pool, riffle, and run patterns and a destruction of the variety and abundance of aquatic habitat.

The increase of impervious surfaces within the watershed will also reduce infiltration and groundwater aquifer recharge. Groundwater that supports the base flow of Plum Run and the hydrology to riparian wetlands in the watershed can also be affected with an increase in impervious surfaces.

Future developments in the watershed will undergo regulatory review for stormwater rate, volume and water quality. Most of the existing developments pre-date existing stormwater volume control regulations and some pre-date existing stormwater rate control regulations. Moving forward, stormwater retrofits for existing urbanized areas should be encouraged through educational programs. Programs with a target audience of homeowners may be particularly effective as potential projects will likely occur on individual parcels. Best Management Practices such as rain gardens, rain barrels, and maintenance of riparian buffers may be most appropriate.

At the municipal level, subdivision and zoning ordinances that are sensitive to the natural resources of Plum Run should be periodically reviewed. Consistency with state regulations is necessary so that land development projects will protect the existing ground water recharge and surface water quality of the watershed.

1.2 Legacy Concerns

While there are few existing farms in Plum Run watershed, a legacy of past agrarian impacts exists in the watershed. Historical land uses that included clearing and grubbing of forests without erosion and sedimentation controls and farming practices that did little to minimize erosion allowed for heavy sedimentation onto the valley floor after European colonization. Dams that were constructed throughout the watershed allowed for sediment to be deposited and cover the floodplain and riparian wetlands. As the dams failed or were breached, knick points formed and cut through the deposited sediment. The legacy of these activities results in a stream that is entrenched in the remaining sediment and largely disconnected from its floodplain (Walter and Merritts 2008). On a geologic scale, the function of the stream may be permanently altered or may one day return. On a biotic scale, it is desirable to immediately restore the function of the ecosystem (as best possible) so that the biodiversity of the natural community may be restored and preserved with the greatest integrity.

2.0 METHODOLOGY

To determine the areas within Plum Run Watershed in need of most attention, Brandywine Valley Association representatives and RETTEW scientists conducted a stream walk in September of 2007. This walk included investigation of the mainstem and major tributaries in the Plum Run Watershed. Photographs, field notes, and GPS locations were collected at areas identified as potential concerns. Where access was not permitted, impacted areas were identified by conducting windshield surveys from roadways and reviewing aerial photography provided by the Chester County GIS Department. Sources of impairment were identified at the landowner level.

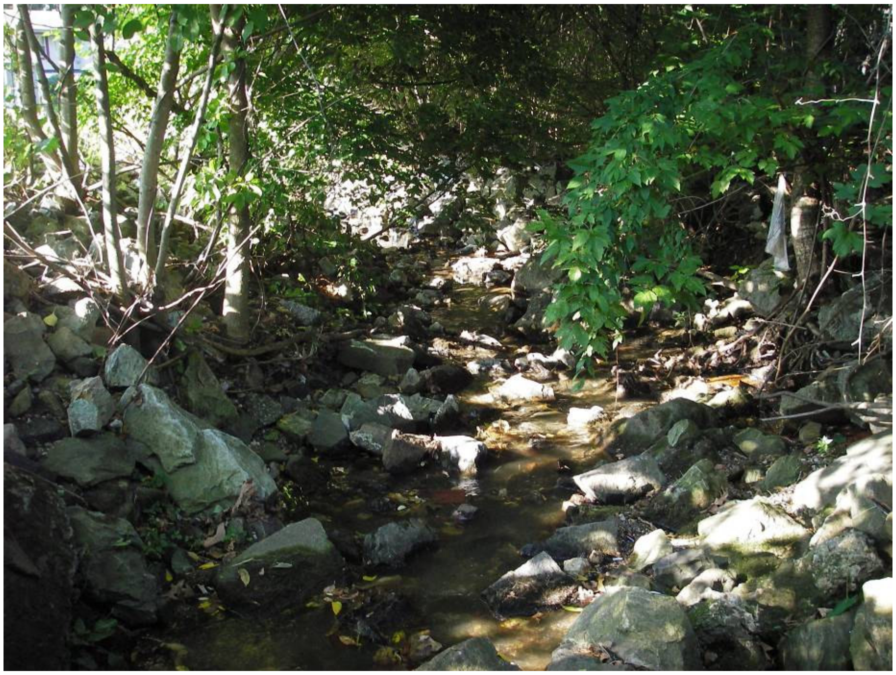
RETTEW located the sample points and other features within the watershed using Trimble Pro XH and Trimble GeoXT, Global Positioning System (GPS) receivers during the site visits. The instrument settings used were: a) Elevation Mask of 15 degrees to limit lowest angle of satellite acceptance to 15 degrees, b) Signal Noise Ratio Mask 6 to minimize weak signal strength, c) PDOP Mask 6 to control the geometry of satellite constellations, and d) Mode Setting Overdetermined 3D which requires a minimum of five satellites for acceptable readings. Logging interval was set at 1 second with typically a minimum of 60 readings collected at each point (Trimble Navigation 1994). Data collected in the field were downloaded to a personal computer for differential correction using GPS Pathfinder Office software (Version 3.1). Correction files were obtained from a dedicated base station located in West Chester, PA. Mission planning, parameter settings, and post processing typically allow an accuracy of less than (<) 1 meter. The precision of GPS collected data is subject to variation caused by canopy cover, atmospheric interference, time of day, and satellite geometry. GPS collected data should not be used in situations involving high property values, controversial projects, or in situations where legal questions may arise (Hook et al. 1995).

3.0 WATERSHED PROBLEMS AND SOLUTIONS

This section focuses on the sources and causes of impairment within the Plum Run Watershed and potential restoration practices that can be completed to address the noted impacts for high and medium priority areas. Each impacted segment identification number can be cross-referenced with its approximate location on the map in Appendix A. Low priority restoration projects are included in Appendix B and are mapped in Appendix A.

3.1 High Priority Projects:

Impacted Stream Segment #53-55:
The West Branch of Plum Run first sees daylight at this outfall below New Street. The water quality is likely impaired as algae scums coat the bottom of the stream. The stream lacks an adequate buffer and has gabion baskets lining the north bank. While the stream is shaded, it is aesthetically impaired by litter that has collected in the channel.



Solution:
Urban stormwater management retrofits that consider volume, rate, and possibly most importantly water quality should be included with any work that drains into Plum Run (including areas that drain via the storm sewer system). Educational programs in this community should focus on the presence and value of Plum Run. Important first steps are stormdrain stenciling, stream signage and a community litter cleanup.

Impacted Stream Segment #8-11:

This section of stream includes a well manicured area with a rip-rap lined streambank. The channel is entrenched, fish habitat is lacking, the bottom is heavily sedimented, no riparian buffer exists to mitigate the effects of any lawn care products that may be applied upslope, and a diversity of riffles and runs is lacking. The streambanks are approx. 5' high, but are stabilized with rip-rap. An exposed pipe in the area of a gas-line crossing should be investigated by the appropriate utility representatives.

Solution:

The effective restoration of this stream segment will largely depend on the willingness of the landowner in altering the riparian area of the property. Reshaping the stream channel to a natural stream geometry would be ideal. This area would also benefit from a fish habitat enhancement project. Placing structures in the stream would aid in transporting sediment through this area and may enhance the aesthetics as the water gently splashes over and through the various structures. The bottom photo (above) shows an example of functioning in-stream structure that is improving habitat in that immediate area. Of great importance is the installation of bioretention areas that will function as small wetlands to mitigate pollutants that are added to the lawn areas adjacent to the stream. Installation of the bioretention areas at the historic floodplain elevation would be ideal.

Impacted Stream Segment #14-15:

The streambanks in this area are approx. 4' high and are eroding. The west bank of Plum Run is mowed right up to the edge of the channel. The east bank is periodically mowed and contains various woodland species including invasive species such as mile-a-minute and Japanese hops. A small tributary, with mowed banks, enters from the west. This tributary is entrenched 3-4'.

Solution:

Streambank stabilization that restores a natural stream channel geometry is neccesssary. Floodplain restoration should also be considered. During the implementation phase of this site, invasive species should be removed and the riparian buffer should be planted with native species to promote biodiverstity. Riparian buffer enhancement and stream channel geometry restoration should be considered for the section of the small tributary immediately upstream of its confluence with Plum Run as a portion of this project. The lack of wetlands at the top of the bank, potential for definite water quality benefits, and potentially easy access to this site make it a good candidate for restoration.

Impacted Stream Segment #19-26:

Remnant of a breached dam breast for the Strode's Mill Dam and confluence with the East Branch of Plum Run. Mowed lawn in a large section of the reach is magnifying the erosion issue. This stream reach has severe legacy sediment impacts that include actively eroding streambanks of the incised channel. The stream segment identified as high priority includes the section with the most severe active erosion. Additional legacy sediment impacts from the mill exist in the area that was likely slackwater upstream of this section as well as on the East Branch. Small tributaries and seeps enter the stream in this section. The three bridges within this section cross overwidened channels and appear to have maintenance issues as sediment is depositing downstream of the structures.

Solution:

Restore the natural stream geometry and restore the floodplain by removing legacy sediment. Temporary stabilization of the streambank should only occur with stream channel geometry restoration as the channel is likely to continue lateral erosion unless the stream's hydrology is considered in the restoration effort. After restoration of the channel, a riparian buffer enhancement project would be appropriate to increase the likelihood of a positive outcome for the project and work to naturally reinforce the streambanks. While this project covers a large area and is potentially the most expensive in the restoration plan, it will also likely have the greatest positive effect as sediment from this area likely impacts the stream all the way to the confluence with the Brandywine. Also important are the minimal number of wetlands that are located on the streambanks which should aid in permitting of the project and not obstruct access to the site. The lack of forest in a large section of this reach should be looked at as an opportunity to begin the project without having to clear and grub or be as concerned with removing invasive rootstock.

Impacted Stream Segment #17:

This impacted stream section begins at the Birmingham Rd. bridge and extends downstream for approximately 500 feet. Downstream of the bridge is the Strodes Mill structure. Strodes Mill is considered historically significant and its preservation is an asset to the community. This structure has experienced flooding issues in the past. The streambanks in this area are vegetated and approximately 3-4' high. The impacted area includes a straight section of stream that is likely not the historic location of the stream channel. Downstream of the straight reach, some riffle, run, pool and glide habitat types are present, but the stream bottom is sediment laden.

Solution:

While a large floodplain restoration project that restores the stream to its pre-European settlement location would be ideal, the constraint of an existing PennDOT bridge should not be underestimated. A suitable alternative approach would minimize project costs, but still minimize flooding risk to the structure and promote biodiversity. An option of installing traditional in-stream deflectors to encourage the channel to move away from the structure during bankfull and lower flows events should be coupled with floodplain restoration on the east side of the stream. The improved floodplain on the east side of the stream would ideally allow flows higher than bankfull to spread out away from the structure. As the east side of the stream is currently in riparian buffer and agriculture, expanding the floodplain in that area may be desirable.

Impacted Stream Segment #97:

A 24" outfall pipe from a stormwater basin behind Swopes Music Building begins the East Branch of Plum Run. Stormwater management from the campus and surrounding areas is lacking due to the lack of stormwater regulation during the urbanization of this area. When present, stormwater management in this area typically focuses on volume control and not water quality. While this stream segment is noted as #97 it includes the urbanized area of the headwaters of the East Branch of Plum Run. A separate unnamed tributary begins at the outfall from the Sikes parking lot and should be included with any stream improvement initiatives in this immediate area.

Solution:

Urban stormwater management retrofits that consider volume, rate, and water quality should be included with any work that drains into the East Branch of Plum Run (including areas that drain via the stormsewer system). Educational programs in this community should focus on the presence and value of Plum Run and things that the homeowner may do to reduce stormwater volume. Particular attention should be given to providing information on construction of small raingardens and use of rainbarrels and stormwater cisterns. Stormdrain stenciling, stream signage and a community litter cleanup would be ideal educational activities. An important first step is involving the community in the Plum Run workshop to be held at West Chester University. Immediately downstream of point #97, a church property may be the best location for a community showcase raingarden project. One opportunity would be to plant the raingarden with biblical plants to demonstrate the bridge between faith and environmental stewardship.

3.2 Medium Priority Projects:

Impacted Stream Segment #4-6:
In this location, remnants of an abandoned bridge are channelizing flow and causing downstream scour. Lawn extends to the top of the streambank on the east side. Invasive bamboo is growing on the west bank.

Solution:
Remove stream encroachments and restore the natural stream geometry. Invasive species removal with riparian buffer enhancement.

Impacted Stream Segment #7-8:
A small on-line dam that is loaded with sediment and includes an intake structure for a larger off-line pond is located at this point. The on-line dam is a likely barrier to fish passage in all but flood conditions.

Solution:
Dam removal with construction of an intake structure that functions without dam construction. The riparian buffer in this section would benefit from invasive species removal and buffer plantings as well.

Impacted Stream Segment #26-28:
This stream section has stable banks, but is entrenched with an approx. 7' high east bank. In the lower 350 ft. of this section, the stream is entrenched 3-4 feet but has stable banks.

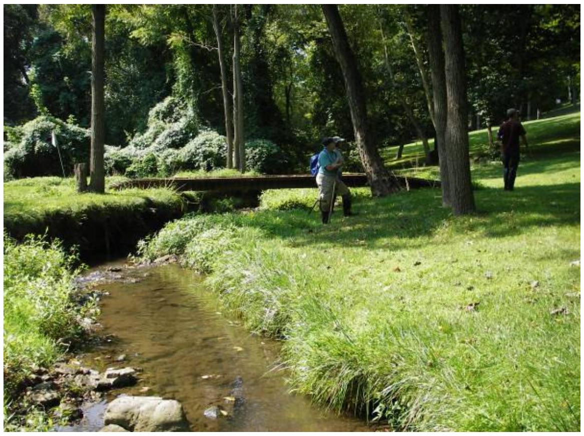
Solution:
The entrenched geometry of this section would benefit from a floodplain restoration project. As the banks appear more stable than several other sections of the stream, this segment should be completed only after the more unstable reaches are restored.

Impacted Stream Segment #32:

A small on-line dam that contains sediment and includes an intake structure for a larger off-line pond is located at this point. The on-line dam is a likely barrier to fish passage. The stream buffer in this area is impacted by some mowing.

Solution:

A dam removal for the on-line dam with installation of an intake structure that is designed to stay free of debris would be appropriate. Riparian buffer enhancements for this area would include native shrub plantings.



Impacted Stream Segment #36-37:

Mowed lawn extends to the top of the bank on the west side of the stream in this section. The streambank is mowed on the east side in a portion of the area. The stream is incised in this area with a 7' high bank eroding on the outside of one meander bend.

Solution:

A streambank stabilization that restores a natural stream geometry to the eroding and incised sections of the streambank should be coupled with a riparian buffer planting project. At a minimum, a homeowner education packet on the effects of lawn chemicals on streams would be appropriate to deliver to this and other homeowners with lawns bordering the stream.

Impacted Stream Segment #46-47:

Heavy stream encroachment exists from this point to the head of the main stem. The streambuffer on the west side of the stream is approximately 10' wide. A garage sits at the top of an eroding streambank in this segment. The restoration options in this heavily impacted area are limited due to the constraints of existing floodway encroachments.

Solution:

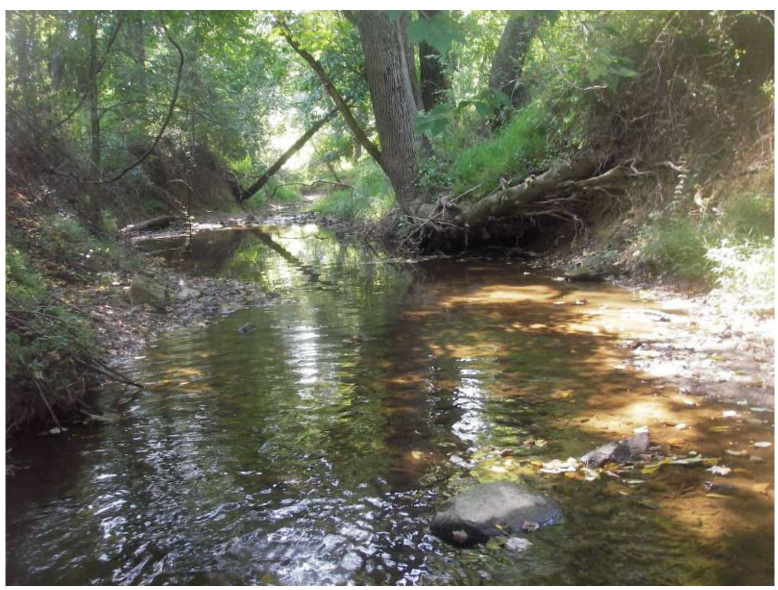
A combination of urban stormwater retrofits and low cost BMPs such as rainbarrels and cisterns may cut down on some of the stormwater volume in this area. Bank stabilization projects in this area should be constructed to use as much natural material as possible to achieve long-term stabilization.

Impacted Stream Segment #50-51:
While not observed on this occasion, reports of soapsuds discharging to the stream in this area exist. The stream has eroded banks and is entrenched approximately 5'. A combination of pedestrian bridges and floodway encroachments limit the amount of channel reshaping that could occur in this area. The picture to the right demonstrates the volume of sediment that exists in this area that disconnects the stream from its historic floodplain.

Solution:
Monitor for wastewater discharges to stream. If additional discharges are observed, coordinate with borough representatives to ensure discharges are connected to the appropriate sewer lines. Where possible, bank stabilization should be considered to minimize erosion.

Impacted Stream Segment #19-65:
This area includes legacy sediment from the Strode's Mill Dam. While the streambanks are 4-5' high with approximately 10' of buffer on each side of the stream, they are not as heavily eroded as the streambanks on the mainstem in this area. The stream appears overwidened.

Solution:
Restoring the natural stream geometry with a floodplain restoration would be very appropriate. Riparian buffer enhancements in this area would include increasing the width of the existing buffer.

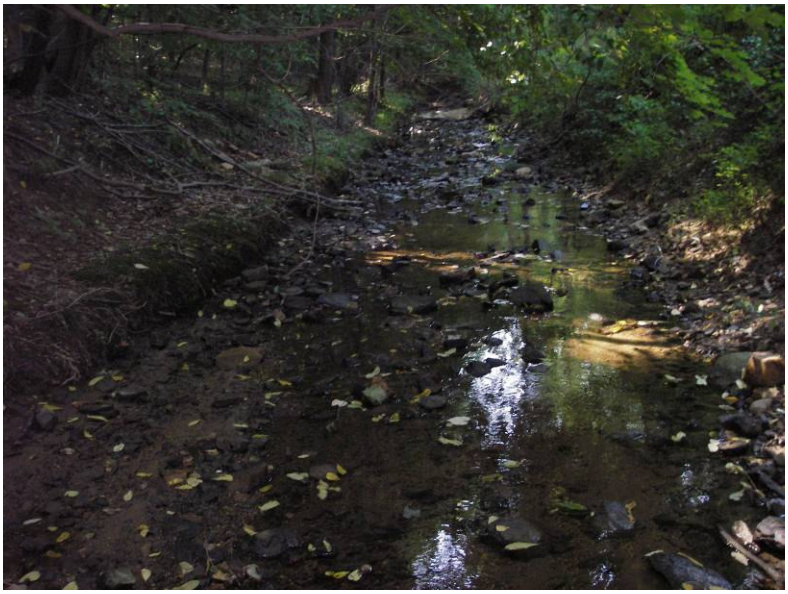


Impacted Stream Segment #65-66:

A cattle pasture exists in this location. The cattle have access to the entire stream corridor and have grazed much of the desirable vegetation. Multiflora rose is growing throughout the pasture.

Solution:

The first priority for this area is to install streambank fencing with stable stream crossings. This would promote herd health and minimize impacts to the stream. The stream buffer should be planted with native vegetation. One complimenting benefit of the streambank fencing project would be to break the pasture into separate paddocks thus allowing the farmer to rotationally graze livestock. This would allow grazed paddocks to recover before livestock are rotated back into that section.



Impacted Stream Segment #76-81:

This stream section is very straight and appears channelized. The stream has the appearance of having been relocated to its current position and is lacking in fish habitat.

Solution:

While restoration of the natural stream geometry and floodplain would be ideal, the location of athletic fields constrain the ability to work outside of the existing stream location. The most immediate stream restoration BMP would incorporate traditional fish habitat enhancement structures with great sensitivity to a naturalized appearance in this natural area. The fish habitat improvement project would address overwidening of the channel in some areas and provide some needed diversity to the straight reaches in this section.

4.0 RESTORATION SOLUTION DETAILS

As was discussed in the previous section of this report, there are many opportunities for improvement. This section discusses specific concerns and conditions related to those improvement activities and best management practices (BMPs).

4.1 Habitat Restoration and Improvement

Streambank Stabilization & Restoration: Streambank stabilization is the most basic step in restoring a degraded stream. Eroded vertical walls or undercut banks are often present where erosion has gone unchecked over time in urbanized and agricultural areas. Traditional streambank stabilization involves: (1) regrading localized laterally eroded banks by grading to a more stable slope (3:1 horizontal:vertical); (2) stabilizing the slopes with erosion control matting and vegetation; and, (3) incorporating in-stream structures and/or bioengineering techniques. Traditional in-stream structures may include toe-riprap, rock cribbing, root wads, and log or rock deflectors. Bioengineering methods that may be incorporated in bank stabilization commonly include fascines, branch packing, brush mattresses, live cribwalls, tree revetments and live staking.

Established streambank stabilization project with root wads.

In-stream structures such as this J-hook can be installed to minimize erosion of the newly restored streambank until vegetation becomes established.

If a stream has been channelized or lacks stream bend meanders and adequate space and funds are available, a natural stream channel design (based on fluvial geomorphology) may be appropriate. Natural stream design uses a stable natural channel ("reference reach") as a blueprint for designing the restoration of the impacted reach. The reference reach provides a suitable pattern, dimension and profile for the design of the restored reach. With a design based on bankfull flow, energy should be managed through the reach to minimize erosion while still transporting sediment from upstream areas through the restored area.

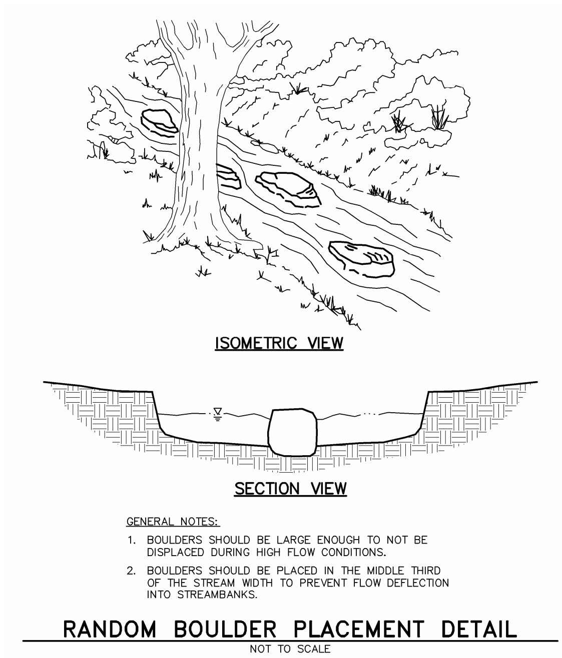
Floodplain Restoration:

Plum Run Watershed has been greatly altered during the period following European colonization. The pre-colonial floodplain has been impacted by a combination of accelerated erosion in the uplands discharging excessive sediment onto the valley floor and constructed dams functioning as sediment traps. As the stream entered each dam, the loss of velocity allowed the stream to drop any sediment it was transporting and cover the pre-dam floodplain. As the dams were breached, the stream quickly cut through the "legacy sediment" and became entrenched. The resultant stream section has a very channelized appearance with steep, eroding banks. Over time, the excess soil in the valley floor is distributed to other areas that were not dammed, as the stream is not yet at a stable state to deal with the excessive sediments that are being flushed through the system.

But just as sediment, fill, buildings and other encroachments were placed into the floodplain, they can also be removed and floodplains re-established. This has been done successfully in many stream restoration projects throughout the Commonwealth. Sometimes restoring a floodplain will also allow for the re-establishment of forest buffers and wetlands.

Sample photograph of floodplain restoration – removing previously placed fill and legacy sediments

4.2 In-stream Habitat Improvements for Fishery



Boulder placements:

This type of fish habitat structure is very inexpensive and easy to install. It involves placing larger boulders (3-foot average diameter) with a track hoe or large backhoe. The large rocks provide instant cover for fish.

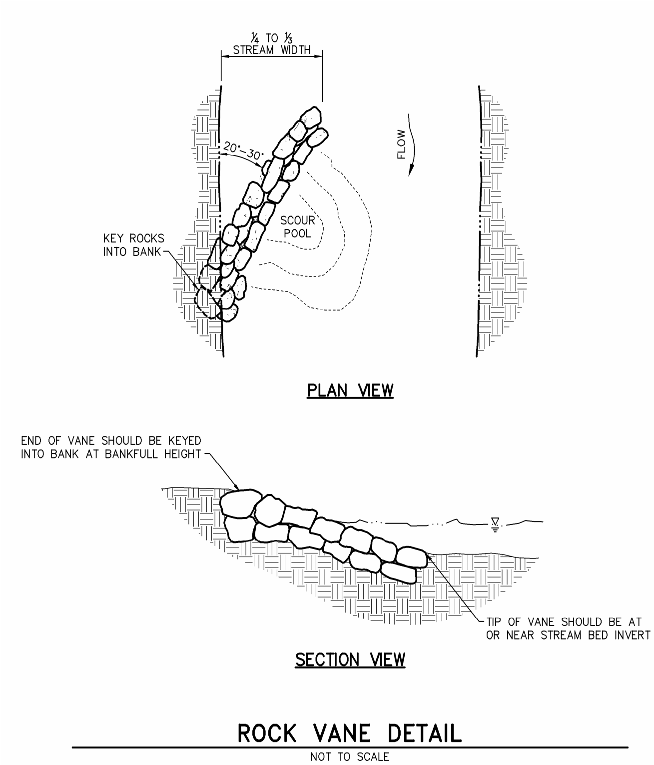
Sample photograph of boulder placements

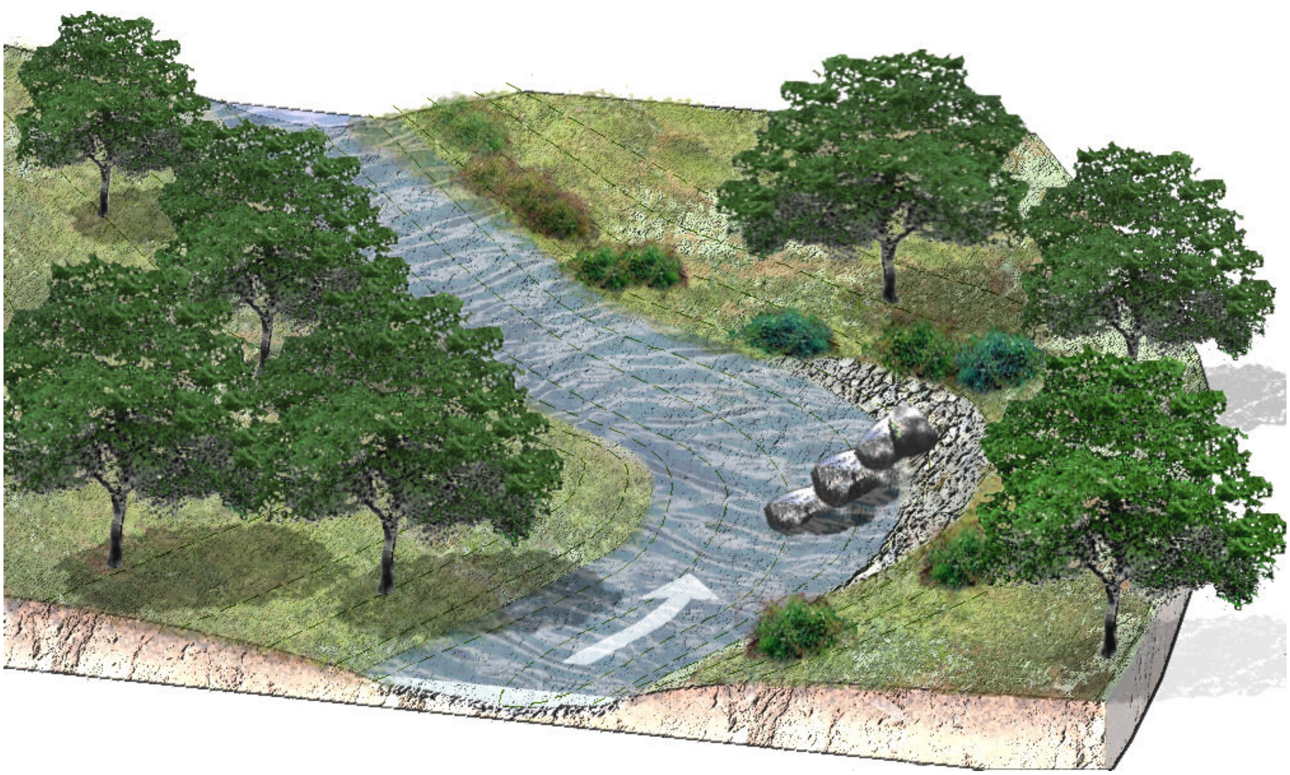
Rock vanes:

Rock vanes are a means of directing stream flow during high water events in order to prevent bank erosion. However, they do need to be properly designed and installed. Rock vanes should be constructed of large rock or in combination with large tree trunks. Rocks that are preferably rectangular in shape measuring roughly 3-feet wide by 5-feet long by 1.5-feet thick should be utilized for proper construction of the rock vanes.

A large track-hoe will be necessary to install these style rock vanes.

Costs will vary due to the availability of such rock in the general area, and ease of access into the work location.

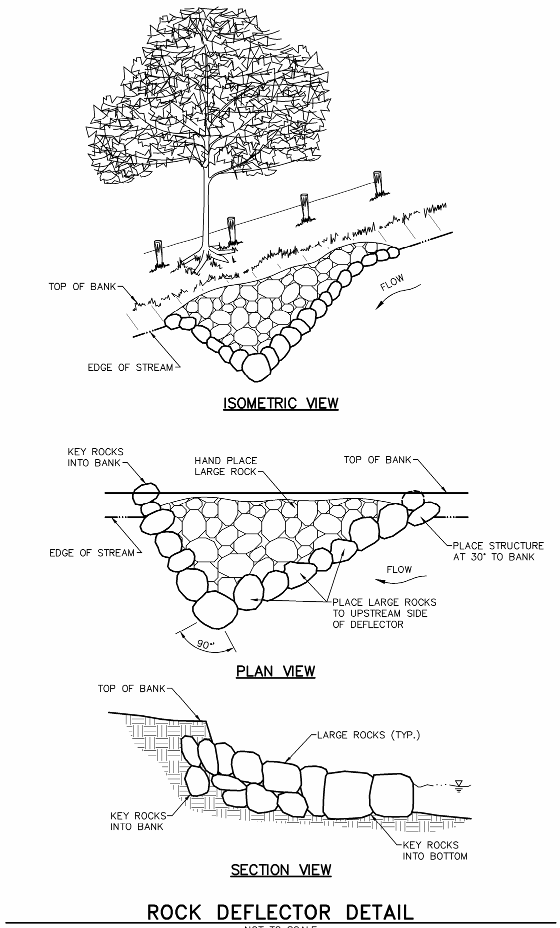


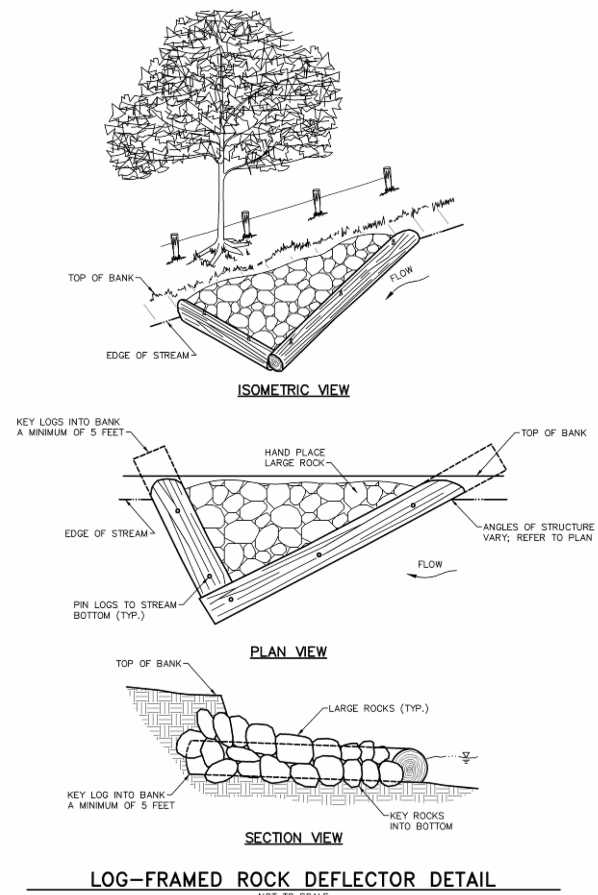


Sample rendering of rock vane

Rock deflectors and log frame deflectors:

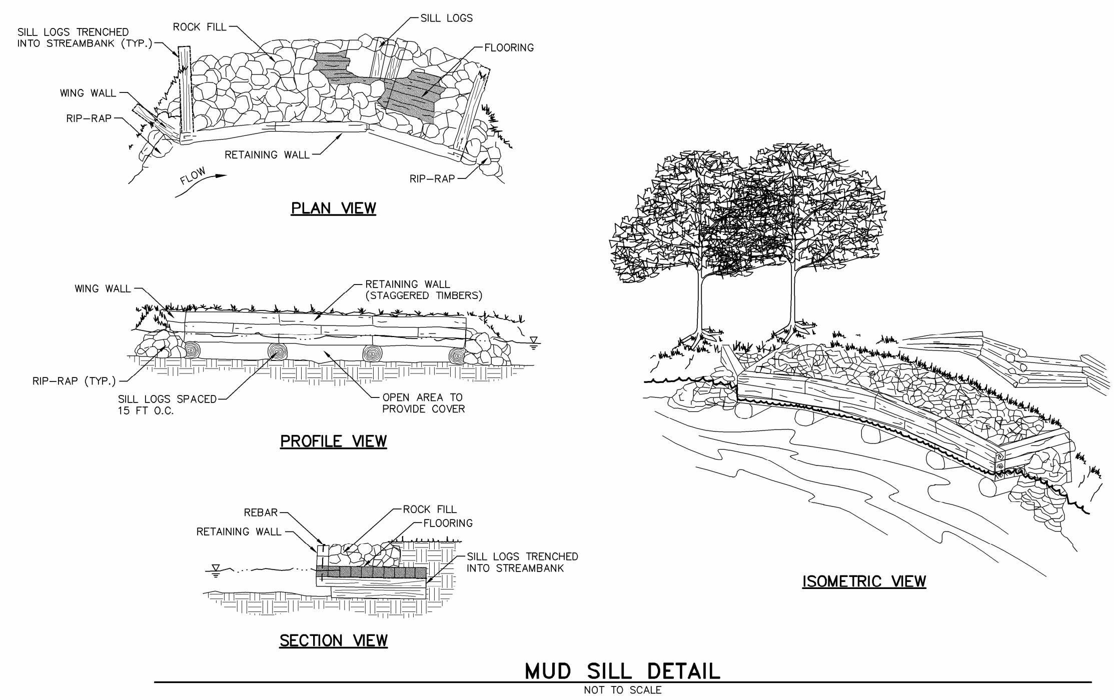
Rock and log frame deflectors are used to stabilize eroding streambanks and provide instream habitat. Rock deflectors are a bit easier to install because the frame of the structure consists of larger rock whereas the log frame consists of logs which have to be drilled and anchored to the substrate. A backhoe is typically needed for construction.





Sample photograph of a newly installed log frame deflector

Mudsills:
Mudsills are bank stabilization devices that are suited for use on the outside bends of eroding banks and are also fish habitat structures. A backhoe or trackhoe is usually necessary for installation.




Sample photograph of a mudsill indicated by the yellow arrow

4.3 Riparian Buffers and Landscaping

Forested riparian buffers have long been recognized as a vital component of stream health in ecoregions where they should be naturally occurring; Plum Run being no exception. Forest buffers provide shade, helping moderate diurnal stream temperatures during both winter and summer months. Water temperature can increase during summer and decrease in winter by removal of shade trees in riparian areas.

Forest buffers act as filters of stormwater runoff during storm events. For this reason, forest buffers are especially valuable in urban watersheds when stormwater can be discharged into a buffer rather than discharged directly into a stream. A wide variety of pollutants such as suspended solids (sediment), nutrients (nitrogen and phosphorus), heavy metals, toxic organic pollutants, and petroleum compounds can be successfully filtered and trapped by the physical structure of the vegetation itself and/or in the case of nitrogen and phosphorus, as well as some heavy metals and toxic organics, be taken up through the root systems and stored in the tree and shrub's biomass (wood).

Sample photograph of a three year old forest buffer planting

Forested riparian buffers serve to stabilize streambanks via the root systems of trees and shrubs which provide deep penetrating structural integrity to the soil. Buffers also reduce the erosive force of stormwater runoff and flood events because the above-ground, physical structure of trees and shrubs slow water velocity via friction. Long-term loss of riparian vegetation can result in accelerated streambank erosion and channel widening, increasing the width/depth ratio.

Riparian trees and shrubs provide terrestrial wildlife habitat. Riparian buffer strips often act as travel corridors for wildlife traveling from one area to another. Additionally, riparian forests serve to provide food, shelter, and nesting areas.

Riparian forests provide a vital function in aquatic ecosystems. Leaf detritus is the main force supporting many lotic (flowing water) aquatic food webs. Large woody debris plays an important role, providing fish and insect cover and spawning locations.

Establishing a successful forested riparian buffer takes careful planning, planting, and maintenance.

The following tree and shrub species are recommended for forested riparian buffer plantings. All species are native and readily available at native tree nurseries.

TREE SPECIES	**HEIGHT (Feet)**	**WILDLIFE VALUE**	**SHADE TOLERANCE**	**SPACING (Feet)**
Red maple (*Acer rubrum*)	75-100	Food source–fruit and young shoots	Tolerant	12-15
Silver maple (*Acer saccharinum*)	75-100	Food source–seeds and young twigs. Good cavity tree	Intermediate	12-15
Shagbark hickory (*Carya ovata*)	75-100	Food source–twigs and nuts	Intermediate	12-15
Persimmon (*Diospyros virginiana*)	50-75	Food source–fruit	Intolerant	10-13
Hackberry (*Celtis occidentalis*)	75-100	Food source–fruit and twigs	Intermediate	12-15
White ash (*Fraxinus americana*)	75-100	Food source–fruit	Tolerant	12-15
Red ash (*Fraxinus pennsylvanica*)	50-75	Food source–fruit	Intolerant	10-13
Eastern white pine (*Pinus strobus*)	75-100	High value food source–needles and seeds. Good cover and nesting tree.	Intermediate	12-15
Sycamore (*Platanus occidentalis*)	75-100	Moderate value for cover and food source–fruit	Intermediate	12-15
White oak (*Quercus alba*)	75-100	Food source–acorns and twigs	Intermediate	12-15
Red oak (*Quercus rubra*)	75-100	Medium value for nesting–food source	Intermediate	12-15
Pin oak (*Quercus palustris*)	75-100	Food source–acorns and twigs	Intolerant	12-15
Black willow (*Salix nigra*)	35-50	Food source–buds, fruit and twigs	Very intolerant	10-13

TREE SPECIES	**HEIGHT (Feet)**	**WILDLIFE VALUE**	**SHADE TOLERANCE**	**SPACING (Feet)**
Sassafras (*Sassafras albidum*)	35-50	Food source–twigs and fruit	Intolerant	10-13
Slippery elm (*Ulmus rubra*)	50-80	Food source–seeds and twigs	Tolerant	10-13

SHRUB SPECIES	**HEIGHT (Feet)**	**WILDLIFE VALUE**	**SHADE TOLERANCE**	**SPACING (Feet)**
White flowering dogwood (*Cornus florida*)	35-50	Food source–fruit	Intermediate	10-13
Redbud (*Cercis Canadensis*)	20-35	Minimal food source–seeds	Tolerant	10-13
Sandbar willow (*Salix exigua*)	15-20	Food source–fruit and twigs	Very tolerant	8-10
Smooth alder (*Alnus serrulata*)	12-20	Food source–fruit	Very intolerant	8-10
Serviceberry (*Amelanchier Canadensis*)	5-25	Food source–fruit, twigs and leaves	Very tolerant	8-10
Buttonbush (*Cephalanthus occidentalis*)	6-12	Food source–fruit	Very intolerant	8-10
Silky dogwood (*Cornus amomum*)	6-12	Food source–fruit	Intolerant	6-8
Grey dogwood (*Cornus racemosa*)	6-12	Food source–fruit	Tolerant	6-8
Red-osier dogwood (*Cornus sericea*)	6-12	Food source–fruit, buds and twigs	Very intolerant	6-8

SHRUB SPECIES	HEIGHT (Feet)	WILDLIFE VALUE	SHADE TOLERANCE	SPACING (Feet)
Winterberry (*Ilex verticillata*)	6-12	Intermediate wildlife value	Intermediate	6-8
Staghorn sumac (*Rhus typhina*)	35-50	Food source–fruit	Very tolerant	8-10
Highbush blueberry (*Vaccinium corymbosum*)	6-12	Food source–fruit	Tolerant	6-8
Northern arrowwood (*Viburnum regonitum*)	6-12	Food source–fruit	Tolerant	6-8

Unfortunately, Japanese hops (*Humulus japonicus*), multiflora rose (*Rosa multiflora)* and mile-a-minute weed (*Persicaria perfoliata)* are very common invasive species within Plum Run Watershed. Species such as these have aggressively invaded riparian corridors throughout sections of Pennsylvania. In many situations, these plants are pioneer species, meaning they are some of the first plants to establish themselves in areas allowed to fallow.

If left unmanaged, these invasive species tend to out-compete desired native species for space and nutrients. The correct natural progression and succession of the desired native plant community can be stalled for years, and in turn negatively impact the rest of the food web.

It is very important to maintain newly planted forest buffers by removing unwanted, invasive species. Mowing, string trimming, and physically pulling out invasive species can be effective ways of dealing with these unwanted "weeds", but many times enough root mass remains and the plant returns. Also, mowing and such other physical removal means are labor intensive and many times not cost effective. Herbicide, when properly applied, can be a safe, efficient means of dealing with invasives.

4.4 Agricultural Improvements

Streambank Fencing: Streambank fencing protects streambanks, promotes re-vegetation, enables forest buffer plantings, protects in-stream habitat and eliminates cattle from entering and loafing in the stream channel. The installation of a two-wire, high-tensile electric fence (powered by AC chargers or solar/battery chargers) is preferred. For construction, eight-foot long locust or pressure treated wooden fence posts should be pounded into the ground on 50-foot centers. Corners should be braced and constructed of 8-foot posts. Temporary poly wire electric fencing can be erected around planted riparian buffers until permanent fencing can be installed.

Cattle Crossing: To direct cattle from barn to pasture or from one pasture to another, cattle crossings can be incorporated as needed into the streambank fence design to allow cattle to cross the stream at selected locations without damaging the integrity of the stream. Cattle crossings should be installed perpendicular across the stream and equipped with electric fence and droppers to deter cattle from wandering upstream or downstream of the crossing. Crossings can be constructed of rock (R-4 rock base covered with 2B stone) or through the use of concrete hog slats set at an 8:1 horizontal/vertical slope cut into streambanks. The center of the crossing should be set at the stream's invert elevation.

Nutrient Management: Nutrient management is a plan for managing the amount, source, placement, form and timing of the application of animal manure, chemical fertilizer, biosolids (sewage sludge) or other plant nutrients used in the production of agricultural products to prevent pollution, maintain soil productivity and achieve realistic yield goals. Nutrient management minimizes agricultural non-point source pollution of surface and ground water resources. Manure management facilities provide the opportunity to apply manure when soil conditions are suitable and crop nutrient needs are high. Manure storage facilities eliminate the need to haul and apply manure daily. Properly designed storage facilities are based on herd size, the area draining to the storage, wastewater and the nutrient management plan for the farm.

4.5 Stormwater Water Volume and Quality Improvement

Potential water volume and quality improvement projects associated with Plum Run should include a combination of existing facility retrofits and innovative applications during new construction. The PADEP BMP manual and the Chester County Conservation District should be consulted for design ideas and requirements. Stormwater volume may be controlled by either infiltrating the stormwater into the ground, capturing the stormwater for use, or evapo-transpirating the water back into the atmosphere.

Infiltration trenches and drywells function to return stormwater directly into the ground and ultimately the underground water table. By collecting rooftop water that should contain minimal pollutants, it may be infiltrated with minimal risk of groundwater contamination. During construction of infiltration devices, the main consideration is minimizing compaction of the soil surface that underlies the stone bed. By utilizing an excavator and scooping the soil back and then placing the stone from above, compaction may be minimized. If built in combination with underground detention facilities, the bulk of the water from a new development can sometimes be infiltrated with minimal impact to the buildable area of a site.

Stormwater capture for use in Plum Run should be encouraged through educational programs. With the environmentally conscious populace of today, the use of rain barrels and cisterns could become commonplace with proper promotion.

Evapo-transpiration is another option for stormwater volume management. The use of rain garden bioretention areas to allow for wetland type plants to filter pollutants and minimize runoff should not be overlooked. A good first step would be holding a stormwater basin workshop that all of the property owners and municipal representatives affiliated with basins would be invited to attend. This workshop could be held in conjunction with a similar workshop for neighboring Radley Run. The workshop could include speakers on maintaining outlet structures, legal issues regarding stormwater basins, and contain a healthy dose of ideas for naturalization of stormwater basins. The financial aspect of not mowing and fertilizing vs. maintenance of a naturalized basin should be included.

Sample photograph of an underground detention facility installation.

5.0 COST ESTIMATES

Costs associated with stream restoration work and the installation of best management practices will vary from site to site within the watershed. This is due to a variety of reasons including but not limited to: ease of access to the construction site, weather and soil conditions, availability of rock and other building materials, any available volunteer hours, and permitting and design costs.

It is always good practice to get a minimum of three bids for both design and construction work. Time should be taken to prepare a thorough "request for bid" which specifically outlines work to be performed to the greatest detail currently known. Contractors should be given ample opportunity to see the proposed construction site so proper evaluation can be made. Keep in mind, an experienced contractor may have suggestions to the "scope of work" outlined within the "request for bid" which may save time and money.

Some requested services may need to be bid on a "time and materials" fashion. Plan design and permitting can fall into this category because aspects of the project will not be known until the design advances to a certain point.

Preliminary probable construction cost opinions are provided as a general guideline of costs associated with each high and low priority project in Appendix D. As the presented range of costs is preliminary, costs should be re-evaluated for the specific project before seeking project funding. It is important to consider in-kind materials and services such as volunteer effort, stream access, and current regulatory guidelines during the re-evaluation. To get a general idea of construction costs to be expected, the following listing is provided based on PRedICT 2007 and the experience of RETTEW:

<u>Equipment with Operator</u>

Back-hoe	$ 75.00/hour
Track-hoe	$115.00/hour
Bulldozer	$ 95.00/hour
Front end loader	$ 90.00/hour
Tri-axle dump truck	$ 85.00/hour
Mobilization costs for large equipment (Requires Penn DOT permit)	$250.00

<u>Materials</u>

Rock (rip-rap)	$15.00/ton delivered
	$26.00/ton installed
	$78.00/linear foot installed
Erosion control matting	$3.00–8.00/square yard installed
Silt fencing	$2.10/foot installed
Super silt fence	$9.00/foot installed
Gabion baskets	$30.00/square yard installed
Geotextile fabric	$ 2.00/square yard installed
Orange construction fence	$ 1.90/linear foot installed

Excavation	
Earthen swales	$ 2.70/linear foot
Basin grading	$ 2.80/cubic yard
Trench work	$ 5.00/cubic yard
Place or strip topsoil	$ 2.10/cubic yard
Backfilling on-site soils	$ 2.60/cubic yard
Clearing and grubbing	$5,000.00/acre
Large tree removal	$ 240.00/tree

Streambank Stabilization Measures–In-stream Habitat Improvements	
Streambank Stabilization	$ 50.00/foot
Gabion baskets	$ 30.00/square yard installed
Geotextile fabric	$ 2.00/square yard installed
Live stakes	$ 1.00–$4.00/stake installed
Fascines	$ 5.50–$22.00/linear foot installed
Natural fiber rolls	$ 61.00/linear foot installed
Live crib walls	$ 11.00–$28.00/square foot of the front face
Root wads	$ 250–$1,125/root wad installed
Boulder placement	$ 583.00/ten boulders installed
Log vanes	$ 400.00/single wing installed
Rock vanes	$ 400.00/single wing installed
"J" Hook vanes	$ 500.00/vane installed
Rock deflectors	$ 400.00/deflector installed
Log deflectors	$ 450.00/deflector installed
Rock weirs (cross-vanes)	$1,300.00/vane installed

Streamside Buffers–Forest Buffers	
Bare root seedling stock	$ .35–$1.50/seedling–not installed
Semi-transplanted bare root stock	$ .70–$2.00/seedling–not installed
Containerized stock (1–2 gallon)	$ 3.00–$7.00/container–not installed
Balled and burlapped stock	$ 25.00–$65.00/tree–not installed
Tree tube protectors	$ .50–$1.30/each–not installed
1 acre of buffer planted in seedlings	$500.00
Reinforcement planting after 2 years	$ 60.00/acre
Mowing and general maintenance	$ 15.00/acre
Herbicide application	$ 60.00/acre
Riparian grass buffer seeding	$175-$400 per acre

Agricultural Best Management Practices	
Conservation Tillage	$ 30.00/acre
Cropland Protection	$ 25.00/acre
Grazing Land Management	$ 360.00/acre
Vegetated Buffer Strip	$ 9,900.00/mile
Terraces and Diversions	$ 500.00/acre

Nutrient Management	$ 500.00/acre
Ag to Wetland Conversion	$13,000.00/acre
Ag to Forest Conversion	$ 6,000.00/acre
Streambank Fencing (high tensile, 2 wire)	$ 1.50–$2.00/linear foot installed
Stone ford cattle crossing	$ 500.00–$700.00/crossing installed
Stoned watering ramp	$ 300.00/ramp installed

Urban Best Management Practices	
Constructed Wetlands	$42,000.00/acre
Bioretention Areas	$ 8,000.00/acre
Detention Basins	$10,700.00/acre

A general rule–The Pennsylvania Department of Environmental Protection typically limits grant funding to approximately $55.00/linear foot for stream channel restoration work (bank stabilization, fluvial geomorphology type work). This includes design, permitting and installation costs.

6.0 OBTAINING SUPPORT AND MONITORING PROGRESS

Education and cooperation of landowners within the watershed to implement BMPs and stream restoration solutions is the key to improving and preserving the natural resources and water quality of the Plum Run Watershed. Educating landowners as to why proposed improvements and changes should occur on their property is extremely important and takes tact, courtesy, respect and sometimes, persistence. Often times if they are clearly shown what is in it for them and helped to visualize the project's goals through actual examples (photographs) of completed projects, they are more likely to want to be a partner in a project. Furthermore, if you are able to communicate what the benefits of sound land management practices could mean to help improve the bottom line of partner farms and businesses, then they will be even more interested. Increases in crop production through preservation of topsoil and a decrease in veterinary bills for treating water borne and transmitted diseases such as mastitis (a painful udder infection that occurs in dairy cows) have a positive monetary effect. Developing a showcase rain garden at a local landscaping/nursery business could potentially allow for new plants to be sold at the business.

The Brandywine Valley Association and BEST's presence in the community should facilitate landowner partnerships. Additional partnering will bring additional professional natural resources specialists into BVA projects and helps to further leverage available grant and funding resources. Some of the important teaming opportunities that are available to the Brandywine Valley Association include:

- Birmingham Environmental Stream Team (BEST)
- Birmingham, East Bradford, West Goshen, and Westtown Townships, West Chester Borough and Chester County Planning Commission (Adoption of protective municipal ordinance language to protect critical watershed resources)
- Chester County Agricultural Preserve Board (Farmland Preservation)
- Chester County Conservation District (Agricultural BMP design, soil conservation and nutrient management, watershed consultation)

- Pennsylvania Department of Environmental Protection (Water quality studies and grant opportunities)
- Pennsylvania Department of Conservation & Natural Resources (Land preservation, resource management and grant opportunities)
- Pennsylvania Fish & Boat Commission (Fisheries management and protection, aquatic habitat improvement)
- Pennsylvania Game Commission (Wildlife protection, habitat improvement and policing)
- West Chester University (Invasive species monitoring, riparian buffer survival studies and macroinvertebrate monitoring)
- Local Scout and Civic Groups (Riparian buffer volunteer planting)

As various watershed projects are completed, periodic monitoring may be helpful to document progress in the watershed. West Chester University would make a great partner for long term monitoring of Plum Run. Collaborating with the university could include providing documentation of restoration objectives and as-built information to the university in exchange for pre and post implementation monitoring. The size and scope of individual projects would determine the level of effort of monitoring. Annual monitoring conducted by successive undergraduate classes may provide baseline data for in-depth research by masters' thesis projects.

One particularly interesting research project would be to follow up on DiFrederico's assessment that fish community diversity decreased with distance from the Brandywine confluence (2007). DiFrederico proposed that fish seeking summer refuge in the Brandywine Creek limits diversity in the headwaters. Here, we identify two fish passage barriers that may potentially contribute to the pattern identified by DiFrederico. Additional research should include sampling immediately above and below the fish passage barrier before and after removal to document any potential impacts of dam removal on the fish community.

7.0 LITERATURE CITED

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APPENDIX A
FIELD INVESTIGATION MAP

APPENDIX B
GPS POINT DESCRIPTIONS AND ACTION ITEMS

GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
1	Confluence of Plum Run and the Brandywine Creek. This section of Plum Run is low gradient and depositional. Several invasive species dominate the understory in this area.	Invasive species removal	Landowner, BEST	Low Priority	
2	32" CMP stormwater outfall.	N/A	N/A	N/A	
3	Upstream edge of the SR 52 bridge and downstream edge of the golf course.	N/A	N/A	N/A	
4	Remnant of an old bridge. Some downstream scour exists below the bridge. Mowed to top of east bank. Bamboo is growing on the west bank from this point to point 6.	Remove stream encroachment, restore stream geometry, invasive species removal, riparian buffer enhancement	Golf course, agencies, BEST	Medium Priority	
5	Outfall from a large pond to the west of the stream.	N/A	N/A	N/A	
6	From this point to Point 8, large trees shade the stream but mowed areas limit the amount of riparian buffer. The golf course is immediately adjacent to the stream on the east bank while a mowed path with sewer line is between the stream and large pond on the west bank.	Riparian buffer enhancement	Golf course, BEST	Low Priority	
7	A small on-line dam that is loaded with sediment and includes an intake structure for a larger off-line pond is located at this point. The on-line dam is a likely barrier to fish passage in all but flood conditions.	Dam removal, riparian buffer enhancement	Golf course, agencies, American Rivers, BEST	Medium Priority	An intake structure for the off-line pond that does not block fish passage should be designed.
8	A forested wet swale enters from the west at this location. Just north of this point the streambanks are mowed to the top of the banks on both sides of the stream and extending to point 11. The channel is entrenched, fish habitat is lacking, the bottom is heavily sedimented, and a diversity of riffles and runs is lacking. The stream banks are approx. 5' high and stabilized with rip-rap.	Fish habitat improvement, installation of bioretention areas, riparian buffer enhancement	Golf course, BEST	High Priority	Restoration designs that evaluate floodplain restoration to create bioretention wetlands should be considered.
9	A small wet swale enters from the east at this location.	Install bioretention areas, riparian buffer enhancement, educational opportunity of naturalized golf course management workshop	Golf course, agencies, BEST	Low Priority	Shallow bioretention areas could aid in filtering pollutants and be designed to be aesthetically pleasing.

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
10	Gas line crossing	Notify utility about exposed pipe	Utility company	Low Priority	The utility lines in this area could control grades of restoration efforts.
11	Looking upstream, the stream has riparian buffers on both sides.	N/A	N/A	N/A	
12	An unnamed tributary enters from the south in this location. While the tributary drains some older development areas, forested buffer and a wetland complex likely mitigate the effects of the development on Plum Run. The streambanks in this area are vegetated and approx. 4' high.	Floodplain restoration	Landowner, agencies	Low Priority	Although a floodplain restoration would be ideal, the stable streambanks in this area decrease the priority in comparison to other areas in the watershed.
13	Looking upstream, mowed lawn extends to the west bank.	Riparian buffer enhancement project tied to segment 14-15	Landowner, local volunteers	Same as 14 below	
14	A small tributary enters from the west with mowed banks on both sides of the tributary. The tributary is entrenched 3-4'. The west bank of Plum Run is mowed to the top of the streambank. The east bank of Plum Run is periodically mowed with some woodland and mile-a-minute and Japanese hops present. The streambanks in this area are approx. 4' high and are eroding.	Streambank stabilization with floodplain restoration, invasive species removal, riparian buffer enhancement	Landowner, agencies	High Priority	The lack of wetlands at the top of bank, potential for definite water quality benefits, and potentially easy access to this site make it a good candidate for restoration.
15	The mowed lawn area extends to this point. Looking upstream a riparian buffer is present on both sides of the stream.	as above	as above	as above	
16	A small spring seep enters from the east.	N/A	N/A	N/A	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
17	Birmingham Rd. bridge. Downstream of the bridge is the Strodes Mill structure. This structure has experienced flooding issues in the past. The streambanks in this area are vegetated and approximately 3-4' high. Working downstream, some riffle, run, pool, glide habitat types are present, but the stream bottom is heavily sedimented.	Floodplain restoration	Landowner, agencies, municipality	High Priority	The option of a floodplain restoration project that focuses on the east bank should be evaluated in comparison to previous designs by others to entirely restore this reach.
18	3 tile drains enter from the west bank.	N/A	N/A	N/A	
19	Remnant dam breast for the Strode's Mill Dam and confluence with East Branch of Plum Run. The legacy sediments are actively eroding by the incised channel from this point to point #26 (and likely extend upstream from that point).	Floodplain restoration with legacy sediment removal	Landowner, agencies, municipality	High Priority	Most expensive project in restoration plan
20	Downstream edge of SR 52 bridge. Downstream of the bridge the streambanks are 5-8' high and heavily eroded. The channel is overwidened.	Same as 19 above	Same as 19 above	Same as 19 above	
21	15" pipe outfall on west bank	Same as 19 above	Same as 19 above	Same as 19 above	
22	Small spring house on west side of stream	Same as 19 above	Same as 19 above	Same as 19 above	
23	Tile drain remnants. The 2-5 foot banks are vegetated in this section.	Same as 19 above	Same as 19 above	Same as 19 above	
24	An unnamed tributary enters the stream from the west. A bridge is located approx. 30' downstream of the tributary. The bridge is overwidened with sediment depositing downstream of the structure.	Same as 19 above	Same as 19 above	Same as 19 above	
25	An unnamed tributary with a palustrine emergent wetland enters the stream from the west. A bridge is located approx. 75' downstream of the tributary. The bridge is overwidened with sediment depositing downstream of the structure.	Same as 19 above	Same as 19 above	Same as 19 above	
26	Downstream end of 8' culvert. Downstream of the overwidened culvert sediment is depositing. Upstream of the culvert, lawn is mowed to both stream banks to point 27. A metal bridge is located in this area.	Riparian buffer enhancement	Landowner	Low Priority	
27	Looking upstream, the riparian buffer improves from this point, but the stream is entrenched.	Floodplain restoration	Landowner, agencies	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
28	Looking downstream, the riparian buffer is in good shape, but is located on a terrace above the stream. The entrenched stream has an approx. 7' high east bank. Downstream of this section, the stream is entrenched 3-4 feet for approximately 350 feet.	Floodplain restoration	Landowner, agencies	Medium Priority	Would be High Priority project but the banks are vegetated in this area.
29	Small unnamed tributary enters the stream from the east.	N/A	N/A	N/A	
30	Downstream end of a bamboo forest area.	Invasive species removal	Landowner	Low Priority	
31	An 8" PVC outfall pipe from the offline pond discharges to the stream in this location. This is the upstream limit of the bamboo forest area.	Invasive species removal	Landowner	Low Priority	
32	A small on-line dam that is loaded with sediment and includes an intake structure for a larger off-line pond is located at this point. The on-line dam is a likely barrier to fish passage in all but flood conditions. Buffer enhancements in this area would be helpful in adding native species as the stream buffer is degraded in this area. A small unnamed tributary enters the stream approx. 80' downstream of the dam.	Dam removal, riparian buffer enhancement	Landowner, agencies, American Rivers	Medium Priority	An intake structure for the off-line pond that does not block fish passage should be designed.
33	A spring seep enters the stream from the east side at this location. The stream has 1-2 foot banks in this section.	N/A	N/A	N/A	
34	A stream crossing with three pipes for the Plum Run Development is located at this point. The roadway fill that is intermittently mowed includes the east streambank. Downstream of the crossing, an unnamed tributary enters the stream from the east and probably includes discharge from a small sewage treatment plant.	Floodplain restoration	Municipality	Low Priority	Removal of the roadway fill is un-likely and would have little measurable effect on water quality
35	18" SLCP (pipe) outfall likely stormwater	N/A	N/A	N/A	
36	Looking upstream from this point the stream is mowed to the top of bank on the north side between this point and point 37. On the south side of the stream, the vegetation is mowed to the top of the bank for the last approx. 100' immediately downstream of point 38. A small pedestrian bridge and a golf hole cross the stream in this area. The stream is incised in this area with a 7' high bank eroding on the outside of one meander bend.	Riparian buffer enhancement, streambank stabilization	Landowner, agencies	Medium Priority	
37	Looking upstream from this point, the stream buffer is adequate on both sides of the stream.	N/A	N/A	N/A	
38	6" terra-cotta tile drain on the north side of stream	N/A	N/A	N/A	
39	32" SCP outfall to stream from an upstream stormwater basin. Scour erosion has caused the end section to drop into the stream and has eroded banks approximately 3'.	Scour protection	Landowner, agencies	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
40	Upstream end of 6' CMP culvert for Bradford Avenue and SR 52. Some roadway drainage enters the stream in this area.	Vegetated filter swale implementation	PennDOT, agencies	Low Priority	
41	Upstream end of 25-50' of masonry walls along the stream bank and a relic bridge. At the downstream end of the stone wall section a small patch of bamboo is growing on the north bank. Several plastic bags of grass clippings were in the floodway.	Remove stream encroachment, invasive species removal, litter cleanup	Landowner, agencies	Low Priority	
42	A sewage treatment pumping station is located at this point. A gasline crosses the stream at this location and appears to be controlling the stream grade from this point upstream. Moving upstream from this point to point 44, stream buffer is lacking on the north side of the stream.	Riparian buffer enhancements. Ensure any future alterations to the gasline profile are evaluated for effects of changing grade control of stream.	Landowners, borough council, utility company, agencies	Low Priority	
43	15" SLCP outfall	N/A	N/A	N/A	
44	Bank encroachments along the north side of stream give way to a small buffer moving upstream. The banks are incised approximately 3 feet. Restoration in this area is constrained by the number of outfalls, property boundaries, and grade control of utilities under the stream.	Riparian Buffer Enhancements, Urban Stormwater Retrofits	Landowners, agencies, borough council	Low Priority	
45	At this location a 4" tile drain discharges to the stream. Two pipes cross under the stream and have degraded metal casings. The pipes appear to be sewer system related.	N/A	N/A	N/A	
46	6" terra-cotta tile drain that appears blocked outfalls to the stream. The tile drain is approximately 20' upstream of an 18" RCP that is rusted out on the bottom and 45' upstream of a garage that is located at the top of an eroding bank. Upstream of this point, the stream buffer is approximately 10' wide on the north side of the stream with the bank heavily eroded. The stream buffer on the south side of the stream is approximately 100' wide.	Bank stabilization, riparian buffer enhancements, urban stormwater retrofits	Landowners, agencies, borough council	Medium Priority	
47	15" CMP outfall, looking downstream approximately 25' a 24" CMP outfalls to the stream. Approximately 25' farther downstream, a 24"SLPP outfalls to the stream.	N/A	N/A	N/A	
48	12" CMP outfall with a pulsed discharge possibly from a sump pump	N/A	N/A	N/A	
49	15" SLCP outfall structure that lacks scour protection at the outfall	Install scour protection	Borough council	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
50	4" PVC outfall structure discharges in this location. BVA rep. has received reports of soap suds discharging to the stream in this area. Several small pedestrian bridges cross the stream in this area. The stream has eroded banks and is entrenched approximately five feet.	Monitor for wash water discharges to stream, bank stabilization	Borough council, landowners, agencies	Medium Priority	The stream is severely impacted in this area, restoration is limited by heavy urbanization.
51	Bank discharge, stormwater from alley discharges in this location.	Urban stormwater retrofit	Borough council	Low Priority	
52	Culvert under a small alley. Downstream end of pipe is causing some erosion. The stream is incised in this area.	Streambank stabilization	Borough council	Low Priority	
53	End of gabions and university parking lot along the north side of stream. A stormwater outfall exists at this location.	Urban stormwater retrofit	WCU	Low Priority	Included as high priority site 53-55 in restoration plan.
54	8" Terra-cotta outfall pipe that is likely from stormwater or tile drains	N/A	N/A	N/A	
55	Outfall to headwaters of west branch below New Street. Algae/scums coat the bottom of the stream in this area and indicate excess nutrients are likely entering the stream. Gabion baskets line the north bank looking downstream. The stream is shaded, but it is channelized with less than 5 feet of buffer on each side. Litter is present in the stream.	Urban stormwater retrofits, stormdrain stenciling, litter cleanup, stream signage	WCU, landowners, borough council	High Priority	
56	Looking downstream, a forested shrub-scrub wetland exists between this point and SR 52. The stream is entrenched 3-4 feet, but the banks are stable. Below SR 52 the tributary is mowed to both streambanks to the confluence with Plum Run. Looking upstream the east bank is mowed to the top of the bank. The western stream buffer is intermittently mowed.	Riparian Buffer Enhancement	Landowner	Low Priority	The section of tributary below SR 52 is included with the high priority project at point 14.
57	Looking upstream, the riparian buffer improves from this point.	N/A	N/A	N/A	
58	A small walking path crosses the stream in this area of open space. Multiflora rose and mile-a-minute are common throughout this tributary including this area.	Invasive species removal	Landowner	Low Priority	
59	A building is within 15 feet of the stream. Looking upstream, the east bank is mowed within 15 feet of the stream. Downstream of this point, a small spring enters the stream. A horse pasture follows the stream for approx. 30 ft. with a 10 ft. buffer.	Riparian buffer enhancement	Landowner	Low Priority	
60	Looking upstream the forested buffer improves. Several drainage tiles discharge to the stream in this area. The stream banks are 1-2 feet high.	N/A	N/A	N/A	
61	An on-line stormwater basin is located at this point. The basin requires maintenance as there is some sediment buildup and the outlet structure is not permanently seated on the riser structure. Mowed lawn exists to within 5 feet of the stream for approximately 50 feet downstream of the basin berm.	Stormwater basin maintenance, small riparian buffer enhancement	Landowner	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
62	PVC tile drain outfall from the south side of stream.	N/A	N/A	N/A	
63	An on-line mill pond is located at this point with the remnants of an old mill structure remaining. Looking downstream, the stream buffer is approximately 50 feet wide on each side. Evidence of past pasturing exists. The stream is on bedrock and erosional evidence is only present on the outside of the meander bends. Several stormwater BMPs are present in the development with one basin being naturalized.	Naturalize detention basins	Landowners	Low Priority	
64	Marlin St. culvert pipe. Looking upstream, a large wetland drains into the culvert. Lawns are mowed to the edge of the wetland.	Riparian buffer enhancements	Landowners	Low Priority	
65	Downstream of this point to Point 19 the streambanks are 4-5' high with approx. 10' of buffer on each side of the stream. The banks are in better shape than the mainstem banks in this area.	Restore natural stream geometry, floodplain restoration, riparian buffer enhancement	Landowners, agencies	Medium Priority	
66	Looking downstream to Point 65, a cattle pasture exists. The cattle have access to the entire stream corridor in this area. Multiflora rose is growing throughout the pasture.	Streambank fencing, install cattle crossings, riparian buffer enhancement, invasive species removal	Landowner, NRCS, Conservation District	Medium Priority	
67	Confluence with a small unnamed tributary.	N/A	N/A	N/A	
68	A palustrine emergent wetland enters the stream via an unnamed tributary from the west bank. The stream channel is incised with 3-4' banks. The banks are vegetated in this area and appear relatively stable.	Floodplain restoration	Landowner, agencies	Low Priority	
69	Confluence of East Branch and unnamed tributary. The tributary has 1-2 foot streambanks that are stable in this area. A heavy deer browseline exists in this area that is likely limiting the biodiversity of this area.	Integrated deer management	Landowner, agencies	Low Priority	
70	New St. crossing of the East Branch with 2 large culverts. Looking downstream, a forested buffer exists on both sides of the stream.	N/A	N/A	N/A	
71	Downstream end of a bamboo forest area on west bank. Looking downstream, an open lawn area extends from this point to point 70.	Invasive species removal, riparian buffer improvement	Landowner	Low Priority	
72	Upstream end of a bamboo forest area on the west bank.	Invasive species removal	Landowner	Low Priority	
73	A stormwater pipe and possible sanitary sewer outfall release is located on the west bank in this area. Garbage has been dumped in this area from the university access road.	Litter ceanup	WCU students	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
74	A small spring seep discharges to the stream from the east bank.	N/A	N/A	N/A	
75	An 18" stormwater outfall is located on the west bank. This section of stream has nice boulders and diverse habitat.	N/A	N/A	N/A	
76	A large culvert at this location is for the access road to Gordon Natural Area. Looking upstream, the stream is very straight and appears channelized from this point to point 81. The stream has the appearance of having been relocated to its current position and is lacking in fish habitat.	Fish habitat improvement, restore natural stream and floodplain geometry	WCU, agencies	Medium Priority	Restoration of this section of stream would be very difficult due to the location of existing athletic fields.
77	Pumping station relief valve on the west bank. The stream in this section has riparian buffers on both sides of the stream. A high deer population is heavily browsing the understory.	N/A	N/A	N/A	
78	18" stormwater outfall from the west bank.	N/A	N/A	N/A	
79	Confluence of Gordon Natural Area unnamed tributary and East Branch of Plum Run. The unnamed tributary is entrenched approx. 4'.	N/A	N/A	N/A	
80	A jogging trail bridge and a stormwater outfall from the athletic fields encroach on the stream in this area.	N/A	N/A	N/A	
81	A palustrine emergent/shrub/scrub wetland with a small unnamed tributary enters from the west. Looking upstream from this point to point 83, there is a great deal of sediment on the bottom of the stream.	Fish habitat improvement	WCU, landowners, agencies	Low Priority	
82	Outfall pipes from the swimming pool in this area are creating erosion gullies. From this point to point 81, a number of dace were found dead in the stream.	Stabilize outfall swales	Landowner, agency	Low Priority	
83	Pump station overflow outfall	N/A	N/A	N/A	
84	Downstream edge of bridge at the Roslyn Swim Club	N/A	N/A	N/A	
85	A CPP stormwater outfall is located on the west side of the stream. The outside of a meander bend has been stabilized with rock.	N/A	N/A	N/A	
86	In this area the stream is overwidened and is eroding the stream banks. Large trees shade the stream, but the understory is mowed to the streambank. Looking downstream, a nice buffer is present.	Native shrub plantings	Landowner	Low Priority	
87	Looking downstream, buffer both sides with 2-3 foot eroding banks and intermittent flow. Looking upstream, mowed within 0-5 feet on both sides of the stream extending to point 85.	Riparian buffer plantings, educational buffer planting booklet and streamside landscaping video	Landowners, DEP (booklet)	Low Priority	
88	Stormwater outfall on east bank	N/A	N/A	N/A	
89	Tile drain discharging from east bank	N/A	N/A	N/A	
90	A small intermittent tributary enters from the east	N/A	N/A	N/A	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
91	2-32"culverts. Downstream of the culverts the stream is entrenched approx. 4'. Flooding concerns from residents.	Evaluate culvert sizing, restore natural stream geometry	Borough council, landowners, agencies	Low Priority	
92	Looking upstream the buffer is approximately 15 feet wide on both sides of the stream. Looking downstream the buffer is 0-5 feet wide to mowed lawn.	Riparian buffer enhancement	Landowners, DEP (booklet)	Low Priority	
93	A small tributary enters from the west and originates near Sikes. A concerned resident indicated that the 2-36" pipes in this area were recently installed to handle increased flooding from development upstream. Dace were present in this area.	N/A	N/A	N/A	
94	36" metal pipe crossing. The stream has no flow in this section as it has infiltrated. The stream in this section is channalized with a stony bottom.	N/A	N/A	N/A	
95	PVC drain pipe that possibly takes excess water from a swimming pool. The stream bottom is overwidened and full of sediment. The buffer is 3-5 feet wide to mowed lawn looking downstream.	Rainbarrels and gardens may enhance this neighborhood	Landowners	Low Priority	Rain gardens may help with infiltration into the groundwater that may help maintain stream baseflow.
96	Looking upstream, mowed lawn extends to the top of the banks on both sides of the stream. A bioretention wetland that would be installed in this area may help improve water quality. Looking downstream, the riparian buffer is 10-20 feet wide to mowed lawns.	Bioretention area, riparian buffer enhancements	Landowner, agencies	Low Priority	
97	24" outfall from basin that begins the East Branch of Plum Run. The basin is behind Swopes Music Building. Stormwater from the campus and surrounding areas typically focuses on volume control and lacks water quality BMPs.	Urban stormwater retrofits, stormdrain stenciling, litter cleanup, stream signage	WCU, landowners, borough council	High Priority	
98	This unnamed tributary originates from the storm sewer systems of the General Howe area. The tribs have stable banks and flow into a large basin that is dominated by *Phragmites.*	Invasive species removal, stormwater management retrofits	Landowners, local volunteer groups	Low Priority	

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GPS Point Descriptions and Action Items

Point #	Description	Action Item	Key Partners	Red-Blue Priority	Comments
99	This tributary includes a wooded corridor that is dominated by invasive species. At the point location, a breached dam is in place with some erosion in the sediment above it.	Invasive species removal, restore stream geometry	Landowners, agencies, local volunteer groups	Low Priority	The small volume of water in this trib. compared with the mainstem and East Branch of Plum Run limit the priority of restoration in this area.
100	The intermittent tributary originates in a residential area above this point. This section of stream was dry during the field investigation. Stormwater from development at the top of the tributary may be contributory to the incised stream channel.	Stormwater management retrofits in headwaters of trib.	Landowners	Low Priority	
101	A large concrete outfall in this location is the origination of a small intermittent tributary. The outfall drains a large stormwater basin that receives flows from Sikes parking area. The basin contains emergent wetland plants	Stormdrain stenciling, urban stormwater retrofits	WCU, landowners, borough council	Low Priority	

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APPENDIX C
POINT LOCATION DATA

Point Location Data

Point #	Northing	Easting	Approx. Elev.
1	218412.04	2563898.59	173
2	218768.20	2563744.06	184
3	218817.26	2563792.73	185
4	218941.83	2563791.79	185
5	218982.71	2563771.15	181
6	219060.62	2563838.82	174
7	219627.01	2564031.70	184
8	219721.48	2564010.71	175
9	220259.50	2564337.10	181
10	220767.98	2564573.16	189
11	221353.72	2565229.57	187
12	221715.83	2565495.95	210
13	222071.65	2565415.56	191
14	222433.43	2565557.44	197
15	223005.35	2565849.63	201
16	223449.65	2566309.32	207
17	224146.20	2566617.59	220
18	224223.29	2566692.11	220
19	224631.77	2566858.61	224
20	224906.17	2566812.81	260
21	225151.11	2566625.69	233
22	225415.45	2566707.01	234
23	225562.42	2566764.12	229
24	225946.82	2566953.10	237
25	226391.45	2567205.15	244
26	226427.20	2567520.12	257
27	226405.54	2567830.95	253
28	226634.60	2568404.66	272
29	227141.63	2568590.51	289
30	227334.32	2568484.03	286
31	227484.05	2568539.98	290
32	228072.70	2568612.57	298
33	228468.17	2568804.05	294
34	229381.38	2568496.57	318
35	229461.31	2568522.77	314
36	229750.87	2568425.55	317
37	230015.94	2568578.60	334
38	230128.57	2568657.90	331
39	230290.53	2568805.66	333
40	230409.22	2569011.04	354
41	230646.17	2569209.74	370
42	230756.97	2569139.33	354

Point #	Northing	Easting	Approx. Elev.
52	231901.62	2569738.90	388
53	232077.48	2569811.92	363
54	232294.76	2570039.25	379
55	232420.00	2570119.96	391
56	223005.56	2565124.97	211
57	223379.33	2565272.63	226
58	223548.42	2565201.38	222
59	224265.98	2564207.49	242
60	224421.98	2563930.54	260
61	224683.88	2563793.09	278
62	224876.35	2563784.84	279
63	225370.83	2563785.78	311
64	225710.41	2563836.38	311
65	224555.77	2568018.14	234
66	224947.37	2568715.69	245
67	225104.66	2569395.88	239
68	225359.23	2569912.74	258
69	225460.92	2570685.58	259
70	225701.18	2570785.00	263
71	225897.26	2570945.18	270
72	226016.01	2570964.51	276
73	226264.71	2570932.86	285
74	226423.89	2571020.86	296
75	226562.05	2571193.04	298
76	226869.94	2571555.60	304
77	227714.39	2571745.07	321
78	228323.39	2571754.35	321
79	228625.94	2571759.18	338
80	228864.68	2571751.59	328
81	229042.17	2571792.95	346
82	229261.38	2571968.27	364
83	229617.45	2571930.55	341
84	229648.16	2571952.13	361
85	229867.73	2571965.51	359
86	230161.78	2572253.41	376
87	230355.09	2572439.51	355
88	230415.49	2572464.34	358
89	230466.40	2572476.25	365
90	230549.96	2572474.57	369
91	230715.04	2572438.76	377
92	230918.72	2572367.29	373
93	231132.14	2572273.55	375

Data is based on State Plane Coordinate System PA South, NAD83 datum.

Point Location Data

Point #	Northing	Easting	Approx. Elev.
43	230831.71	2569161.71	381
44	231144.04	2569073.63	354
45	231273.78	2569112.37	393
46	231344.27	2569169.52	385
47	231385.71	2569255.96	380
48	231481.67	2569332.71	367
49	231513.23	2569384.66	372
50	231746.73	2569657.30	372
51	231865.13	2569711.73	372

Point #	Northing	Easting	Approx. Elev.
94	231257.23	2572273.36	384
95	231351.01	2572348.07	387
96	231426.57	2572439.02	390
97	231835.95	2572563.10	392
98	223937.85	2568606.04	252
99	226036.73	2571969.76	297
100	228602.32	2573339.55	384
101	231163.99	2571993.60	384

Data is based on State Plane Coordinate System PA South, NAD83 datum.

APPENDIX D
PROBABLE CONSTRUCTION COST OPINION

RETTEW
We answer to you.

Plum Run Watershed Preliminary Probable Construction Cost Opinion

Site	Min Cost	Max Cost
53-55	$5,000	$100,000
8-11	$85,000	$160,000
14-15	$45,000	$75,000
19-26	$445,000	$600,000
17	$50,000	$80,000
97	$5,000	$100,000
4-6	$4,500	$8,500
7-8	$6,500	$10,000
26-28	$60,000	$100,000
32	$4,500	$8,500
36-37	$15,000	$25,000
46-47	$5,000	$20,000
50-51	$5,000	$10,000
19-65	$175,000	$350,000
65-66	$8,000	$20,000
76-81	$30,000	$45,000
Total	$948,500	$1,712,000

*Minimum costs for this item include only a mini-grant for environmental education; maximum costs include BMP retrofits.

RETTEW Associates, Inc. is not a construction contractor and therefore probable construction cost opinions are made on the basis of RETTEW's experience and qualifications as an engineer and represent RETTEW's best judgment as an experienced and qualified design professional generally familiar with the industry. This requires RETTEW to make a number of assumptions as to actual conditions which will be encountered on the site; the specific decisions of other design professionals engaged; the means and methods of construction the contractor will employ; contractors' techniques in determining prices and market conditions at the time, and other factors over which RETTEW has no control. Given these assumptions which must be made, RETTEW states that the above probable construction cost opinion is a fair and reasonable estimate for construction costs but cannot and does not guarantee that actual construction cost will not vary from the Probable Construction Cost Opinion prepared by RETTEW.

APPENDIX E
PROFESSIONAL QUALIFICATIONS

Aaron S. Clauser, Ph.D., CPESC - Dr. Clauser has his bachelor's degree in Biology and Environmental Studies from East Stroudsburg University of Pennsylvania and a doctorate in Environmental Science from Lehigh University. Dr. Clauser is a Certified Professional in Erosion and Sediment Control. He has experience as an environmental regulator with the Berks and Schuylkill Conservation Districts where he has served at both the technician and managerial levels. Dr. Clauser has given oral presentations at conferences held by the Ecological Society of America, American Society of Limnology and Oceanography, Pocono Comparative Lakes Program and Schuylkill and Berks Conservation Districts and has collaborated on an article published about Pacific Northwest amphibians in a peer-reviewed journal. Dr. Clauser has completed numerous training courses including DEP sponsored NPDES, Chapter 102 and 105 technical seminars, Applied Fluvial Geomorphology for Engineers (FGE) by Wildland Hydrology, Inc., and Environmentally Sensitive Maintenance of Dirt and Gravel Roads Training. He is familiar with the 1987 *Corps of Engineers Wetland Delineation Manual*. Dr. Clauser has both conducted and been accepted as an expert witness regarding wetland delineations. Dr. Clauser served in the PA Air National Guard where he attained the rank of Staff Sergeant. His doctoral dissertation entitled "Zooplankton to Amphibians: Sensitivity to UVR in Temporary Pools" includes quantitative optical and organismal level models that are extended to landscape level variations in pool optical properties and population level sensitivity to UVR.

Mark A. Metzler, NICET II – Mr. Metzler has an associate's degree in Wildlife Technology from the Pennsylvania State University and is certified by the National Institute for Certification in Engineering Technologies in Land Management and Water Control/Erosion and Sediment Control. Mr. Metzler has ten years experience working in the environmental regulatory community (Lancaster County Conservation District) and six years of private consulting experience. He received training in both the 1987 Corps of Engineers Wetland Delineation Manual and the 1989 Federal Manual from both the PA Dept. of Environmental Protection and the US Corps of Engineers. In addition, he received soil mechanics training from the US Dept. of Agriculture – Natural Resources Conservation Service. As an environmental regulator, Mr. Metzler reviewed, permitted, and inspected over 2,000 various plans and project sites many of which involved impacts to Waters of the Commonwealth (wetlands, rivers, lakes). Mr. Metzler has prepared three TMDL implementation plans for the Commonwealth of Pennsylvania and US EPA, as well as numerous watershed assessment and river restoration plans. He is also experienced in dam removal design, the issue of legacy sediment and has overseen dam removal and fish migration projects within Pennsylvania, Maryland and Virginia.

Jonathan P. Kasitz – Mr. Kasitz has a bachelor's degree in Biology/Ecology from Millersville University. He has used the 1987 Corps of Engineers Wetland Delineation Manual for numerous field delineations in PA, MD and NY. He has completed the U.S. Army Corp of Engineers' Wetland Delineation Course. He has also been trained in several different stream assessment protocols, both in the eastern U. S. as well as in the Rocky Mountain region. Mr. Kasitz participated in internships with the PA Department of Environmental Protection in their Water Quality division and with the PA Department of Military and Veteran Affairs as a Biology Tech at Fort Indiantown Gap. He has worked with various government agencies including the National Park Service at Yellowstone NP and the US Forest Service in Colorado. He has performed biological surveys for many different threatened and endangered species across the country. He also completed honors research on the effects of ponds on stream nitrate levels in Lancaster County while at Millersville University.

Joel M. Esh – Mr. Esh has an Associate in Specialized Technology Degree in Computer Aided Drafting and Design from York Technical Institute and 6 years of experience at RETTEW. He is responsible for the technical workload of the Natural Sciences department, including computer-aided drafting and design (CADD), global positioning systems (GPS), and geographic information systems (GIS). He has created and been involved with the design of stream restoration plans, dam removal plans, pond restoration plans, wetland mitigation plans, and wetland delineation plans. Additional training has included Introduction to Stream Processes and Ecology by Canaan Valley Institute and West Virginia University. When working in the field, he has assisted with data collection and surveying for stream design and wetland delineations in PA, NY, and DE using the 1987 Corps of Engineers Wetland Delineation Manual. Utilizing GIS information, he has obtained and analyzed information for watershed assessments and created maps for grant applications and other uses. He has also been involved with cultural resources by performing site visits for documentation of buildings and bridges and creating plans for historic survey forms. In his first four years at RETTEW, he worked in the Transportation Engineering department, where he has directed data collection, prepared traffic engineering analysis, and completed PENNDOT plans involving right-of-way, traffic signals and highway occupancy permits utilizing PENNDOT resources.