OLDE SKUNKY
STREAM STUDY

Newtown Borough
Bucks County, Pa
File No. 09-02048Y

DRAFT
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Prepared For:

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I. Project Description:

Newtown Borough, on behalf of the property owners, has obtained funding to perform an engineering study to address concerns regarding erosion, sedimentation, flooding, potential for standing water and mosquito breeding, structure undermining, and general safety. The focus of this study is to quantitatively assess the erosive potential of Olde Skunky, suggest ways to reduce that potential, and, where a reduction in flow is not possible, provide or suggest measures and construction details for keeping Olde Skunky at bay through efforts expended by the property owner or by the Borough as a sponsor working with the property owner or by some other grantee of public funds working with the property owner.

II. Scope of Project:

The stream study included the collection and analysis of anecdotal, as well as empirical, data on the Olde Skunky channel. A questionnaire was circulated to property owners which abut the channel and to Borough officials and other interested citizens so that important historical facts, concerns, etc. about the channel might be incorporated into the study. This information was analyzed to identify those areas of the channel which are perceived to be of concern in terms of erosion or flooding.

The stream itself was analyzed the utilizing hydrologic/hydraulic modeling software so as to compare the channel capacity (full bank) to the two-year storm flow. This stream flow was be used to determine what measures could be used to stabilize the channel, or to determine to what amount of the flow should be reduced/diverted to reach bank full capacity. In areas where erosion has occurred or is otherwise in evidence, scenarios have been suggested to amend the existing hydrologic condition to benefit the community by reducing flow and/or erosion of the channel. In addition, a list of suggested maintenance practices for the property owners along the stream has been prepared and distributed. These procedures focus on vegetative management, rather than more intense structural practices.

The capacity and performance characteristics of the existing stormwater management facilities in the watershed were examined to determine what retrofit measures are available and feasible to improve hydrologic conditions in the channel. In particular the Newtown Station detention basin, located on Center Avenue above Lincoln Avenue, was included in the hydrologic/hydraulic model since it is an online facility with significant influence on the downstream channel hydrology of Olde Skunky.

III. Brief History of Olde Skunky

Olde Skunky was originally a stream bisecting the borough starting at the northeast corner and running southwest. It was piped under Washington Avenue and under South State Street, eventually discharging to Newtown Creek. Prior to the late 1960's some alteration of its course occurred, principally in the area of Frost-Watson Lumberyard, which diverted the flow to the perimeter of this property between Centre and Penn Streets. That alignment remained until the

development of Newtown Station by Toll Brothers, recently completed. Another are that was altered was the intersection of Penn and Chancellor Streets where the stream was enclosed from a point between Chancellor Street and Lincoln Avenue to a point below Chancellor Street. This stream enclosure, which remains in place today, has insufficient capacity for the amount of stormwater runoff directed to it causing flooding at the intersection of Penn and Chancellor Streets.

Prior to 1967 the "Hotchkiss" property, located north of Washington Avenue, was farmland in Newtown Township, however that year the property was annexed by Newtown Borough to allow for a new residential development. The plans for the new "Washington Village" were approved, and, in keeping with the standards of design for that era, there was little in the way of stormwater management associated with the development. In the years that followed, increased flooding was noted along Olde Skunky. In 1971 Council authorized a comprehensive plan to be created for Olde Skunky by the Borough Engineer, Pickering, Corts and Summerson (PCS). The engineer reported a cost of $238,037.97 to prepare the plan and work was commenced including a survey of the stream channel at that time. PCS engineer Jan Gouza advised the Council that flooding would increase with completion of the development. The Comprehensive Plan for Olde Skunky was never completed as funding could not be obtained from the Army Corp of Engineers or HUD.

In later years, serious flooding where Olde Skunky crosses under South State Street resulted in the Borough replacing the inlets and pipe in this area. More recently, the construction of the Newtown Station development included a stormwater basin which receives the runoff from north of Washington Avenue and east of Norwood Avenue. This basin provides storage area for flood control purposes and has relieved some of the flooding problems. As of today, Olde Skunky receives approximately 2/3 of the Borough's stormwater runoff.

IV. Data Collection:

Various sources of information were used to generate a model of Olde Skunky Watershed; information from state, federal or county agencies were collected and their applicability confirmed through field inspection of the channel and surrounding areas. In addition to field inspections of the channel, documents and plans on record at the Borough were examined with regard to Olde Skunky. The general characterization of the waterway is that it is stable in most places, yet at the same time exhibits instances of instability and erosion along the channel banks which have been held back or postponed at certain locations by various "home made" improvements along the channel. In most cases, stress along the backyards and sides of private properties where the stormwater is eroding those yards has been observed. Specific sources of information for the study include:

- Maps and studies prepared by Pickering, Corts and Summerson on record at Newtown Borough

- Land development plans showing existing and proposed stormwater management facilities
- Borough of Newtown, Storm Drainage System Plan, last revised February 2006
- Digital aerial photographs
- GIS Mapping and USGS Quadrangle Maps
- Bucks County soils mapping (digital and paper)
- Flood plain mapping
- Field surveys at all road crossings and at critical points along the channel to acquire cross-section data for entry into the hydraulic model

V. Results of Property Owner Survey:

As part of the collection of data, a questionnaire was sent out to property owners along Olde Skunky. Out of 30 surveys that were sent out, 14 were returned, half of which considered the channel to be a threat to their property. When asked to rank the threat-potential of Olde Skunky, the majority of respondents felt the threat was low (0-3) and three felt the threat was average (5 out of 10). Only two residents considered the threat more significant, scoring it higher than 5 out of 10. Five of the residents indicated that the channel was within 50 feet of structures on their property including barns and outbuildings; two have structures within 100 feet, and the remaining seven are more than 100 feet from the channel.

The responses were evenly split regarding flooding and erosion along Olde Skunky, although most noted that the water velocity during rain events was high. Some of the responses noted that they experienced flooding in the past, however the situation was corrected by worked along and within the channel such as maintenance on the State Street culvert and the basin installed as part of Newtown Station Development. One resident adjacent to Newtown Station and Olde Skunky noted that the flooding problems have gotten better since the basin installation, however it does appear that the velocity has increased. There are still some areas that have standing water during heavy rain fall events, and one resident noted that the intersection of Penn and Chancellor Streets floods frequently.

The majority of residents have not performed any modifications to the channel, nor were they aware of work performed by previous owners. Some noted that they have replaced soil and vegetation on the banks where they were eroded; one resident installed a timber retaining wall. One resident observed that the property on the opposite side had gabions or a similar structure installed along the bank in the past, but that resident removed this structure after which erosion in this area increased. One resident identified a retaining wall along the stream channel which was installed prior to their ownership; their neighbors indicated that it was 30-40 years old. Photos of this wall were provided, and had been observed during field investigations as this wall appears to be leaning in toward the stream and, therefore, in need of repair or replacement. Most had no additional comments to make regarding Olde Skunky. One resident noted that they routinely remove debris from the channel that has was downstream, some of it quite large. Another stated that they were not in favor of anything drastic being done to change Olde Skunky as they felt it provided much needed open space within the Borough. They went on to say that this is a flood plain and should not be built on.

VI. Analysis of Data:

The shape of a channel, its width, depth, slope, and how it moves through the landscape, is influenced by the amount of flow the stormwater channel is expected to carry. The channel morphology is determined by the energy of flows that range from "low flow" to "bank full"; the water plus the sediment in that flow determines the total energy which shapes the channel. Bank full flow typically occurs with a frequency of approximately once every eighteen (18) to twenty-four (24) months. During larger flood events, the flow overtops the channel banks and flows into the floodplain with less impact on the shape of the channel. The technical analysis focuses on the two (2) year storm, on the flow rate and velocities in the channel, and the ability of the channel to accommodate the flows from that storm.

The watershed for Olde Skunky was mapped using available GIS and USGS topography. The watershed was then broken down into sub-watersheds based on the storm sewer and its discharge points to the channel. Aerial photographs, from the Delaware Valley Regional Planning Commission 2005 series, were used to generate land use coefficients for each sub-area. The aerial maps were supplemented with information from approved plans for areas such as Newtown Walk and Newtown Station which have been approved since 2005. Time of concentration for each sub-area and for the watershed as a whole was determined via the average velocity method which incorporates surface conditions and land slope to calculate runoff travel time. Runoff values were then calculated using the Rational Method for 2-year and 5-year storm events.

The hydraulic model utilizes as inputs the channel cross section survey data, the pipe crossing survey data, and the output from the hydrology calculations to provide channel flow rates, velocities, and depths along the channel. The data is input into the HEC-RAS computer software available through the U.S. Army Corps of Engineers. This program routes the runoff along the stream and generates a model of the water's flow down the channel, including the backwater effects caused by pipe crossings and flow reductions provided by online detention systems. With the exception of the back-water effect from the culvert under Norwood Avenue, the channel has sufficient capacity to convey the 5-year storm event until it reaches the end of the existing trench drain through the property located at Centre and Lincoln Avenues. From this point to the culvert under State Street, Olde Skunky has insufficient capacity to convey even the 2-year storm event. Although channel velocities vary throughout the system, most cross sections show a velocity at or above five feet per second (fps) which is the maximum permissible velocity for grasses. As a result and as demonstrated in the field, Olde Skunky experiences general bank scour due to excessive velocities and/or shear stress. As is typical for this type of erosion, it is most evident in areas of erodible, unconsolidated material lacking adequate vegetative cover, ie woody vegetation.

VII. Recommendations:

This engineering study provides the necessary technical information upon which designs for specific measures can be based, however the following recommendations are general in nature and intended to provide guidance regarding measures which may be employed to stabilize the channel banks in areas of serious erosion. Some of the measures are relatively

simple and may be employed by the property owner with little direction. Other methods would require a greater effort, including design plans and permits from PA Department of Environmental Protection. These larger projects could be completed through a cooperative effort of both the property owner and the Borough.

1. *Reduction in runoff.* During the analysis of the channel, it was noted that the stream enclosure adjacent to Linton Memorial Park was overloaded. A diversion of a portion of the stream flow was considered as a means to reduce this overload and improve the flow conditions in the stream channel. See map with "HEC-RAS after Proposed Diversion" for locations of Options 1, 2, and 3.

    a. *Option 1, Diversion of flow:* The first option involved the installation of a storm sewer from the stream just above the enclosure, routed through the park and across Penn Street, then along the CVS property to the SEPTA right-of-way. This right-of-way is no longer an active railway, and the Sterling Street crossing has been filled in with a storm culvert at its base. This right-of-way, therefore, would act as a drainage channel with the culvert providing detention above Sterling Street. Although this diversion is feasible, the benefit would be limited for smaller storm events since the pipe intake would only draw a portion of the runoff in the stream. This option would also require the cooperation or permission of the property owners where the storm sewer crosses private property.

    b. *Option 2, Diversion of flow:* The second option would be to divert the stream above the Lincoln Avenue culvert. In lieu of the culvert, the channel would be captured by a storm sewer routed along Lincoln Avenue, behind the curb, until it intersects the storm sewer at Lafayette Street which already discharges to the SEPTA right-of-way. This diversion would be located within the existing rights-of-way, however it may require adjustments to pipe inverts in the existing storm sewer at Lafayette Street. By diverting the runoff from the upstream side of the Lincoln Avenue culvert, the stream flow for the lower section is cut in half. The resultant channel flow would be approximately 18% drop in velocity and 1.70 feet lower water surface elevation between Lincoln Avenue and the stream enclosure, and 15% drop in velocity and 0.50 feet lower water surface elevation below the stream enclosure.

Item:	Unit. Cost	Quantity	Costs
excavation	$2.00 CY	3,227 CY	$ 6,454.00
manifold box	$3,500.00 Ea	3	10,500.00
road restoration	$30.00 SF	1,650 SF	49,500.00
general restoration	$0.75 SF	10,285 SF	7,713.75
58"x91" ERCP	$ 210.00 LF	1,085 LF	227,850.00
TOTAL COST for 1 elliptical pipe			$302,017.75

Item:	Unit. Cost	Quantity	Costs
excavation	$2.00 CY	4,702 CY	$ 9,404.00

manifold box	$3,500.00 Ea	3	10,500.00
road restoration	$30.00 SF	2,700 SF	81,000.00
general restoration	$0.75 SF	16,830 SF	12,622.50
3 48" HDPE pipes	$61.88 LF	3,255 LF	201,419.40
TOTAL COST for 3 pipes, 48" plastic			$314,945.90

Item:	Unit. Cost	Quantity	Costs
excavation	$2.00 CY	2,863 CY	$ 5,726.00
manifold box	$3,500.00 Ea	3	10,500.00
road restoration	$30.00 SF	1,425 SF	42,750.00
general restoration	$0.75 SF	8,883 SF	6,661.88
2 60" HDPE pipes	$106.25 LF	2,170 LF	230,562.50
TOTAL COST for 2 pipes, 60" plastic			$296,200.38

c. *Option 3, Detention of flow:* Another option for reducing the flow in Olde Skunky is to provide additional storage for flood control. This could be implemented independently or in combination with the option 1 or 2 above. There is a vacant lot on the north-east corner of the Penn-Lincoln intersection which is owned by Reading Railroad. This lot could be used to provide a flood control facility either as a surface basin, similar to the basin for Newtown Station Development, or as a subsurface facility which would allow the lot to continue being used for parking. Overflow or outlet for the facility would then be connected back to the existing storm sewer or to the diversion pipe mention in option 2. Costs for this type of facility cannot be estimated without a working design, and it would require the consent of the property owner to utilize the site.

d. *Option 4, Detention of flow:* Similar to option 3, a subsurface facility could be installed at Linton Memorial Park to provide additional flood capacity. This facility would have the additional benefit of not requiring consent of a property owner since the Borough already owns the land. There would be a non-financial cost in loss of use of the park during the work, however this would be temporary as the are would be restored and maintained as lawn. As with Option 3, the overflow or outlet for the facility would then be connected back to the existing storm sewer or to the diversion pipe mention in option 2. Costs for this type of facility cannot be estimated without a working design, and it would require the consent of the property owner to utilize the site.

e. *Option 5, Detention of flow:* Additional detention of the smaller, more frequent storms could be provided in the Newtown Station facility by installation of a flow restriction device. A weir plate with a low flow orifice could be installed which would restrict flows for the 1 and 2 year storms providing a reduction in flow rate. Since this facility is owned by a Homeowner's Association, however, this type of modification typically results in the municipality taking over the operation and maintenance of the stormwater management facility.

f. *Option 6, Reduction of volume:* Further modifications to the Newtown Station facility, whether with Option 5 or independently, would be to lower the floor of the basin to create more of a bioretention facility. This would require some investigation of the underlying soil and geologic conditions by in-situ testing prior to the design of such a system, but could provide significant benefits in terms of water quality and quantity. It would also be recommended that this retrofit be protected from siltation, therefore any large project upstream (ie. Newtown Walk) would need to be stabilized and/or closely monitored to insure that sediment does not compromise the improvements. As noted above, this facility is owned by a Homeowner's Association, and proposing modifications to it may result in the Borough taking over the operation and maintenance in perpetuity.

If both options 5 and 6 were implemented, it would have significant impact on the Olde Skunky watershed. The impacts to water level and velocity in the stream may appear minor, but the major effect would be a reduction in the overall volume of runoff in the stream. Reducing the volume of runoff that is conveyed along the stream, although it may not significantly alter the rate at which it flows, will reduce the length of time that the stream flows at higher capacity. This will in turn reduce the erosive capacity of the stream flows since it will have a shorter period of time in which to act on the stream banks.

g. *Rain Barrels.* The majority of the residential properties in the Borough were installed prior to current stormwater management regulations and, therefore, have no controls associated with them. One way in which home owners can help reduce the flooding along Olde Skunky is to install rain barrels on the downspouts of their homes. They collect the water from the downspout and store it for later use such as watering the garden or house plants. A rain barrel should have a spigot at or near the bottom to drain off the water for use, and it should have an overflow opening for larger rain events. Some maintenance from the home owner would be required, but this is limited to keeping a cover on the barrel to prevent mosquitoes and draining down the barrel between rain storms. Rain barrels are commercially available through various sources with a variety of sizes, appearances, and features; prices range from $50 to $200.

h. *Rain Gardens.* Directing the downspouts into a rain garden is another way to help reduce the flows in Olde Skunky. A rain garden is a decorative landscape area that is depressed below natural grade, rather than mounded above it. The rainwater is collected in the depression where it is taken up by the plants and/or seeps into the ground. The plants in such a garden must be tolerant of periodic flooding, but in all other respects it would be maintained like all other garden area. A rain garden for a house with a roof area of 4,000 square feet would need a rain garden that is 400 square feet in area and 12 inches in depth. The cost for such a garden would vary depending on type of plants installed, but the average cost for a 400 square foot rain garden is noted below.

Item:	Unit. Cost	Quantity	Costs
Excavation	$2.00 CY	55 CY	$110.00
8" pea gravel base	$6.50 CF	267 CF	1,735.50
geotextile fabric	$1.80 SY	60 SY	108.00
amended soil mix	$17.00 CY	30 CY	510.00
estimated plants	$ 1.75 SF	400 SF	700.00
TOTAL COST			$3,163.50

An example of how this would impact the flows along Olde Skunky assuming an average house footprint of 2,000 square feet and that approximately 300 homes were to capture the first inch of runoff from the roof in either rain barrels or in a rain garden. This would remove 50,000 cubic feet of runoff from Olde Skunky, significantly reducing the erosive potential of the stream.

2. *Stabilization of eroded stream banks.* There are several methods of stabilizing the stream banks that could be used along Olde Skunky; these methods are selected based on aesthetic appeal as well as functional ability since the majority of the channel runs through residential areas. The following methods are arranged in increasing order of protection, and their installation is dependant upon the stream velocities anticipated. General unit costs are provided for each method, however total cost would be dependant on the area of work and final design for each section. Details of typical methods of stabilization are provided at the end of the report. Include with these details is a map of Olde Skunky identifying the average velocity which will determine which method of stabilization would be most appropriate.

   a. *Conventional vegetation* – Many areas of the stream channel have velocities that are less than 5 feet per second. These areas would remain stable with landscaping practices that could be performed by the property owner. For best results, the stream channel should have more naturalized vegetation represented by small shrubs and/or taller grasses and plants which are only cut down 2-3 times per year. Lawn or turf grasses should be avoided as they do not protect the soils from erosion within a stream channel. In "Care and Maintenance of Small Streams and other Drainage Channels" there is a list of plant material which is both attractive and highly resistant to erosion. For limited areas of erosion, the plant material may be supplemented with live stakes driven into the unstable area. Any work performed as described could be done by a property owner without need for permits from state or county agencies, provided that the existing embankments are not regraded.

Item:	Unit Cost
shrubs, 36" height	$50.00 ea
plants, 2" plug	$ 2.50 ea (price may vary if using larger plants)
live stakes	$ 6.00 ea

b. *Live Stake Installation* – This type of stabilization is suitable for stream velocities from 4-7 feet per second, and will require a permit due to the slope adjustments. It is best suited to areas where with moderate erosion and sufficient area to modify the stream banks. The method includes re-grading the banks to a more stable slope (3:1 or better) and installing an erosion control fabric over the slope. The live stakes are then used to anchor the fabric. It may be combined with toe protection measures such as rip-rap, biologs or longitudinal peaked stone toe protection.

Item:		Unit Cost
slope grading	$ 2.50	CY
topsoil & seed	$ 2.00	CY
erosion control mat	$ 3.00	SY
live stakes		$ 6.00 ea

c. *Live Fascines Installation* – This type of stabilization is suitable for stream velocities from 6-9 feet per second, and will require a permit due to the slope adjustments. It is best suited to areas where with moderate erosion and sufficient area to modify the stream banks. Like live stakes, this method includes re-grading the banks to a more stable slope and installing an erosion control fabric over the slope. In this case however, the bank is terraced with trenches for the fascines and can have up to a 1:1 slope. It may be combined with toe protection measures such as rip-rap, biologs or longitudinal peaked stone toe protection.

Item:		Unit Cost
slope grading	$ 2.50	CY
topsoil & seed	$ 2.00	CY
erosion control mat	$ 3.00	SY
live fascines		$11.20 LF
live stakes		$ 6.00 ea (1 per 3LF of fascine)

d. *Toe Protection* – Toe protection can be used in combination with other methods or independently. There are three types of toe protection that can be used.

i. Biolog: coconut fiber logs approximately 12" in diameter confined by jute-twine netting; biologs are staked into the ground at the toe of the slope with at least ½ below normal water surface; 2" plant plug are installed into the log; provides long term protection, but eventually degrades leaving established vegetation

ii. Rip-Rap: stone toe protection sized per stream velocities, average stone size 9-12 inches (R-5 to R-6); non-woven geotextile installed under stone; provides long term toe protection without degradation; works well along the bottom of retaining walls to prevent scour which may undermine the wall

iii. Longitudinal Peaked Stone Toe Protection (LPSTP): similar to rip-rap protection with greater variety in stone sizes; benefit over rip-rap is that this

stone is 'self-leveling' which means that it will shift to fill in scour holes that develop at the base of the stone and provide increased protection; provides long term toe protection without degradation; works well along the bottom of retaining walls to prevent scour which may undermine the wall

Item:	Unit Cost
Biolog + plants	$ 24.00 LF
Rip-rap	$ 42.00 CY
LPSTP	$ 60.00 CY

e. Brush Mattress Installation – This type of stabilization is suitable for stream velocities from 8-12 feet per second, and will require a permit due to the slope adjustments. It is best suited to areas where with moderate erosion and sufficient area to modify the stream banks. Like live stakes, this method includes re-grading the banks to a more stable slope, preferably 3:1 slope. Toe protection is installed, and then the brush mattress begins above that protection. The mattress is made up of a layer of willow and dogwood branches which provides immediate protection against erosion and allows sediments to deposit in and around the branches. Both the branches and the live stakes used to anchor them will eventually grow to a dense covering of vegetation for long term stability.

Item:	Unit Cost
slope grading	$ 2.50 CY
rip-rap	$42.00 CY
brush mattress	$36.00 SY (includes fascine & live stakes)

f. Rip-Rap with Joint Plantings – This type of stabilization is suitable for streams with high velocity flow, the size of the stone increases with higher velocities, and will require a permit prior to installation. The rip-rap can be installed at up to a 2:1 slope. The joint plantings are live stakes which are long enough to penetrate the stone and extend into the underlying soils. Once the stake begin to grow, they will soften the look of the rip-rap without removing the hard armor protection that it provides. The live stakes need to be longer than in other applications, and will require more effort to install.

Item:	Unit Cost
rip-rap	$42.00 CY
live stakes	$ 9.00 ea

VIII. Sources of Funding:

Many of the recommended stream stabilization methods noted are eligible for state or federal funding which may be applied for by the local municipality. Some of these funding sources require a certain percentage of matching funds or services from the applicant, a.k.a.

Newtown Borough, which can take the form of design services or work being performed by Borough personnel. State funding may be obtained through the Pennsylvania Department of Environmental Protection's (PaDEP) Growing Greener Grant Program. Federal funding may be obtained through U.S. Environmental Protection Agency's Section 319 Program and the National Oceanic and Atmospheric Administration's (NOAA) Coastal Zone Management Program. It should be noted that public funding of projects on private property will require an agreement between the property owner and Newtown Borough which will permit personnel to enter the property and perform the work. This agreement will also assign maintenance responsibilities to the property owner for a period of 20 years, as required by PaDEP. It is necessary, however, for Newtown Borough to take the lead on these projects because this type of funding is rarely if ever awarded to an individual property owner.

There are additional sources of funding for work associated with storm sewers and/or stormwater management facilities; again some of these sources require a percentage of matching funds. State funding sources include the Growing Greener Grant Program, Stormwater Management Planning and Implementation Program, and PennVEST Low Interest Loan Program. Federal sources include those mention above and FEMA's Pre-Disaster Mitigation Program. A more complete list of funding sources, and the application requirements for same, is available on the PaDEP's website :

http://www.dep.state.pa.us/grantscenter/GrantAndLoanPrograms.asp

CARE & MAINTENANCE of
SMALL STREAMS AND OTHER DRAINAGE CHANNELS

There are many things that you, the home owner, can do to help maintain the stream channel so that it flows freely and minimizes erosion along its banks. When properly maintained, a stream channel can be an attractive addition to your property's landscape and will provide habitat local bird populations. Although there are some stabilization methods that require permits from state and county agencies, the information provided here can be performed by anyone for little or no cost.

1. Regular Maintenance

A. Stream banks should be maintained with 100% vegetative coverage, preferably a combination of woody shrubs and herbaceous plants. Attached is a list of plants and shrubs which are known to provide excellent soil stabilizing characteristics. The use of turf grasses along stream banks should be discouraged as they provide no resistance to erosion.

B. Vegetation should be mowed no more than two to three times per year. Minimum height of vegetation when mown shall be four (4") inches.

C. Any erosion, slumping or other soil disturbances that are noted should be immediately repaired. Repairs may be made using river rock or compacted soil immediately re-vegetated with recommended herbaceous species. If the area is larger than 1000 square feet, local and county permits may be necessary.

D. All trash and debris shall be removed when such materials are observed. In particular, any object that might form an obstruction in the channel should be removed.

E. Grass clippings and other lawn debris shall not be disposed of within stream channel or along the banks of same.

2. Routine Maintenance

A. Vegetation shall be inspected at the beginning of each growing season and replaced or supplemented as needed.

B. Herbaceous plants may be installed above the water line without the need for permits if the slope of the banks are to remain the same. Refer to attached list for recommended erosion resistant species.

C. Woody shrubs may be installed above the water line without the need for permits if the slope of the banks are to remain the same. Live stakes may be installed anywhere on the banks. The recommended species on the attached list will root from cuttings of the branches and may be used to supply live stakes for other areas. Attached are instructions for the harvesting, storing, and installing of live stakes from existing plants.

HERBACEOUS PLANTS

BOTANICAL NAME	COMMON NAME	PLANTING ZONE (as measured from water surface)	SHADE TOLERANCE	VALUES
Aster novae-angliae	New England Aster	> 1 ½ ft		
Carex stricta	Tussock Sedge	0 - 1 ½ ft	partial to full shade	Forms strong hummocks
Eupatorium purpureum	Joe-Pye Weed	1 ½ - 3 ft		
Iris versicolor and pseudacorus	Blue and Yellow Flag	0 – 1 ½ ft	Full sun	Showy blue/yellow flowers
Hybiscus moscheutos	Swamp Mallow	0 – 1 ½ ft	Partial shade	Showy pink or white flower, hummingbird food source
Juncus effuses	Soft Rush	0 – 1 ½ ft	Prefers full sun, will tolerate partial shade	Food/habitat for small mammals and birds
Lobelia cardinalis	Cardinal Flower	0 – 3 ft	Partial shade	Bright scarlet flower, hummingbird food source
Lobelia siphilitica	Great Blue Lobelia	0 – 3 ft	Partial shade	Showy blue flower
Panicum virgatum	Switch Grass	> 1 ½ ft	Full to partial sun	Nesting habitat for small mammals and birds
Asclepias incarnate	Swamp milkweed	0 – 1 ½ ft	Full sun	Pink flowers, good butterfly plant

WOODY PLANTS & SHRUBS

BOTANICAL NAME	COMMON NAME	PLANTING ZONE (as measured from water surface)	SHADE TOLERANCE	VALUES
Salix purpurea	Streamco basket willow	Any	Full sun, tolerates partial shade	Provides habitat for small mammals and birds
Salix x cottetii	Bankers dwarf willow	0 – 1 ½ ft	Full sun, tolerates partial shade	Provides habitat for small mammals and birds
Salix discolor	Pussy willow	0 – 1 ½ ft	Partial shade	habitat for small mammals and birds, attractive landscape species
Cornus stolonifera	Red twig dogwood	0 – 3 ft	Partial shade	Bright red winter twigs, white berries in fall
Cornus amomum	Silky dogwood	1 ½ - 3 ft	Partial shade	fall and winter forage for small mammals and birds
Cephalanthus occidentalis	Buttonbush	0 - 1 ½ ft	Partial to full sun	Flood tolerant, provides forage for wildlife
Forsyhis sp.	Forsythia (many varieties)	> 3 ft	Full sun	Bright early spring flowers
Ilex verticillata*	Winterberry*	1 ½ - 3 ft	Partial shade	Bright red berries in winter, winter food source
Viburnum dentatum*	Arrowwood viburnum*	1 ½ - 3 ft	Partial shade	Good late summer fruit

*plant stock only. Does not root well from cuttings.

HARVESTING AND HANDLING OF WOODY CUTTINGS

A large portion of bioengineered stabilization techniques involve the use of woody species of plants that from adventitious roots from cuttings. Live cut plant material can be taken from existing, healthy, native growing sites or from healthy specimens of previously planted material or may be purchased from nursery stock. A mixture of species should be harvested whenever possible; preferable species for bioengineered stabilization include 'Streamco' purple osier willow, 'Bankers' dwarf willow, and 'Ruby' red osier dogwood which are easy to clone and produce roots readily from cuttings.

Plant Selection

When choosing live plant material for erosion control applications, young wood (less than 1 year old) or suckers will often sprout the easiest. However older wood (2 to 5 years old) has greater energy reserves which is necessary to consistently sprout, and it is much stronger. For cases where the cuttings will be bundled or grouped, best results come from mixing younger wood with older wood keeping the majority of the wood in the 2-5 year old range. There are two types of cuttings:

1. Stakes: ¾ to 2 inches in diameter, 16-36 inches in length, side branches should be cleanly removed, but bark remain intact
2. Branch cuttings: can have smaller diameter branches (3/8 inch) combined with medium diameter branches (1 inch), branch length can be 3-9 feet long depending upon the intended application, use for fascine bundles or brush mattress

Timing

Timing is an important consideration in harvesting cuttings. It is preferable to install the cuttings within one week of harvesting, although this time frame may be extended if the cuttings are handled properly. Also, there must be sufficient soil moisture to insure satisfactory root formation once it is planted. The optimum time to plant live cuttings for south-eastern Pennsylvania is in October and November which provides a longer period of time for the roots to establish before the dry summer months.

Harvesting Cuttings

Harvest should be taken from live wood at least 2 years old, with smooth bark that is not deeply furrowed and is relatively straight. Cuttings should be taken from inside the crown of the plant and should be spread throughout the stand to minimize visual impact. In general, one should avoid thinning more than 2/3 of the donor plant to avoid harming it. If performed carefully, pruning will not harm the shrub and will often invigorate the plant to produce an abundance of whips for harvest in a couple of years.

Cuttings for live stakes should be trimmed of all side branches, however some side branches may be left on branch cuttings intended for fascines and/or brush mattresses. Terminal bud (the bud growing at the tip) should be trimmed so the plant energy will be rerouted to the lateral buds and adventitious tissue.

Soaking and Storage

Cuttings should never be allowed to dry out or be left in direct sunlight. They may be stored in a cool, humid, dark place for up to 6 months if the conditions remain stable. Cuttings should be soaked in water for a minimum of 24 hours prior to installation, preferably 5 to 7 days. Soaking will stimulate the rooting process, but the cuttings should be removed before the root tips emerge (typically in 7-9 days). Once removed from the water, the cuttings should be immediately transported to the site and planted.

Requirements for Woody Cuttings:

Sunlight and Exposure: Willows and other plant dependant upon direct sunlight for proper growth will thrive on a south or west facing slope. Materials which prefer partial shade would do better on north or east facing slopes. It should be noted, however, that even if the cuttings do not thrive, they may provide sufficient stabilization to allow native species to take hold and grow. See plant specifications for sun/shade preferences.

Soil Moisture: As with any plants, woody cuttings require adequate soil moisture. If planted too late or not deep enough, a cutting will not develop sufficient roots to survive the dry season by tapping into ground water or the capillary fringe. On the other hand, if it is planted in a saturation zone (below ground water), the plant will not have sufficient aerated pore spaces and it will drown. (See plant specifications for bank placement.) Live stakes, for example, should be of sufficient length that the basal end of the stake is at or near ground water, with approximately 6 inches exposed on the surface. Where the stake is installed closer to the water surface this length may be much shorter than for a stake that is installed near the top of the bank.