Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Sandwich, MA • 02563
Phone - 508-833-6600 • Fax - 508-833-3150 • *www.horsleywitten.com*

Bare Hill Pond
Stormwater Management Assessment
Final

Town of Harvard, Massachusetts

June 2, 2008

Submitted to:
Bare Hill Pond Watershed Management Committee
Town of Harvard
13 Ayer Road
Harvard, MA 01451

Submitted by:
Horsley Witten Group, Inc.

TABLE OF CONTENTS

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Bare Hill Pond Watershed

Bare Hill Pond is a 321-acre, municipally-owned pond located in Harvard, Massachusetts in the Nashua Basin (DEP, 1999). The study area includes eight drainage areas encompassing a drainage area of approximately 90 acres draining to the northeast corner of Bare Hill Pond. As a former sheep meadow, the shallow pond now maintains an extensive peat bottom and is a prime candidate for plant growth. Multiple studies of the pond have concluded that eutrophication is accelerating due to natural and development-related nutrient loading from the pond's watershed as well as from septic systems (Whitman and Howard, 1987; DEP, 1999; ENSR, 1998). Since the Town's swimming beach is proximate to the contributing watershed, the management of bacteria is also a high priority. Stormwater management measures have been identified as necessary to control and manage the current and future sources of nutrient, sediment, and bacteria loading from within the contributing watershed to the northeast corner of the pond.

1.2 Project Background

The Horsley Witten Group, Inc. (HW) was retained by the Town of Harvard and the Bare Hill Pond Watershed Management Committee (BHPWMC) to assess the study area and recommend stormwater best management practices (BMPs) to control nutrient loading (most notably, phosphorus) to the pond. The results from this assessment will be used as part of a grant application to the Massachusetts Department of Environmental Protection's Section 319 Grant program. The assessment is comprised of the following items: a delineation of the contributing drainage areas in the project area, estimation of sediment and phosphorus loading from the contributing areas, schematics for structural best management practices appropriate for treatment of the estimated pollutant loading, planning-level construction cost estimates for BMP implementation, and a ranking of the proposed BMPs based on estimated total phosphorus removal potential.

2.0 EXISTING WATERSHED CHARACTERISTICS

2.1 Existing Stormwater Infrastructure

The existing stormwater management in the study area includes infrastructure such as catch basins along paved roadways that discharge runoff via stormwater pipes into tributaries to Bare Hill Pond directly or into the surrounding woods. Other paved roads simply sheet flow to either side. A few sites in the study area already incorporate stormwater BMPs. For example, the reconstructed library site utilizes a bioretention area, sediment forebay, and detention pond for stormwater management; and the Bromfield School has existing proprietary treatment devices and a detention pond.

2.2 Existing Land Use

The Bare Hill Pond Watershed generally consists of forest, agriculture, low-density housing, and mixed-use commercial. The study area (the northeast corner) has the highest intensity land use of the watershed, consisting of medium density housing, public institutions (schools, library, etc.), and the Harvard Village Center. In addition, the entire study area is in a Zone II for two public water supply wells located near Bare Hill Pond, with a small portion located within the Zone I for these wells. The eight targeted drainage areas within the study area are described below. The study area and environmental constraints are shown and labeled in Figure 2-1.

BHP-1 – Intermittent Stream

This retrofit site is located along a path in the woods behind the Bromfield School tennis courts, in a small clearing near a stream and an abandoned well. The stream is identified as an intermittent stream on the USGS topographical map for this area, and it flows into Bare Hill Pond along the western side of the Bromfield School ball field. The stream flows through a culvert under the gravel path at this location.

The drainage area for this site covers a large area (approximately 25 acres) with 23% impervious cover. The land use consists of mainly medium- and low-density residential, some commercial/institutional, and forest. Potential sources of pollutants in this drainage area are road runoff, parking lot runoff, and residential lawns, which may contribute excess fertilizers and pesticide to stormwater runoff. The stream in this area has a large, wooded buffer and appears to have a stable, non-eroding streambed and banks. The soils were formed from compacted till, and large glacial erratics and/or rock outcrops are present. This site is located in priority and estimated habitat as identified by the Massachusetts Natural Heritage and Endangered Species Program (NHESP).

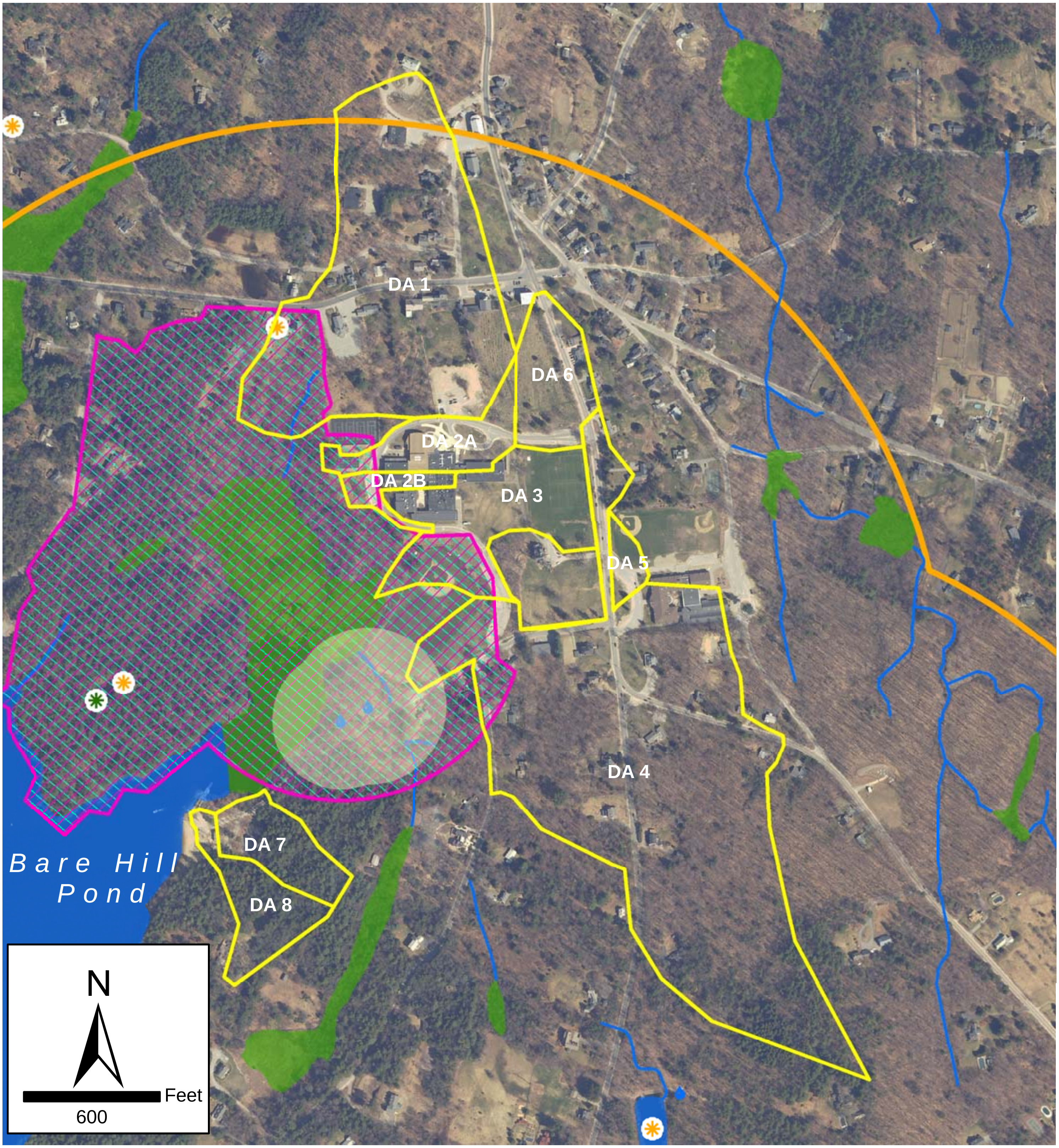
BHP-2 – Bromfield School Detention Pond

The Bromfield High/Middle School was renovated in 2001. As a part of this construction, two detention ponds were built to manage the stormwater runoff from the access road, parking lots, athletic courts, and a majority of the roof runoff. Detention Pond 2 was identified as a potential retrofit site. This is the larger of the two ponds and is located immediately to the west of the school. The drainage area to this pond is 5.3 acres, which is comprised of mostly impervious cover (67%) associated with the school, as well as a small portion of the adjacent cemetery. Potential sources of pollutants in this drainage area are road and parking lot runoff.

The pond has roughly 29,000 cubic feet of storage. There are three inlets to the pond, and one outlet control structure with three orifices at varying elevations that discharges into the woods behind the pond. Two proprietary stormwater treatment devices (Stormceptor) are used for pretreatment at the two main inlets that carry road runoff (the third inlet only drains an athletic court). The pond currently supports a shallow pool and wetland vegetation. This site is also located in priority and estimated habitat as identified by NHESP.

BHP-3 – Bromfield School Ball Field

The drainage area to this study site consists of almost 17 acres, most of which is comprised of school property. The renovated library is located within this drainage area, as well as the drainage area described under BHP-6. When sizing BMPs for this site, the impervious cover associated with the library and the Bromfield School entrance road (BHP-6) were not included in the calculations with the assumption that these areas will already be treated upgradient. Thus for



Legend

- Drainage Areas
- Wetlands
- Surface Water
- Streams
- NHESP Certified Vernal Pools
- NHESP Potential Vernal Pools
- NHESP Priority Habitats of Rare Species
- NHESP Estimated Habitats of Rare Species
- Interim Wellhead Protection Areas (IWPA)
- Zone I
- Public Water Supplies

Horsley Witten Group
phone: 508-833-6600
www.horsleywitten.com

Constraints Map
Bare Hill Pond
Harvard, MA

4/13/08 mw
J:\7143 Bare Hill Pond\GIS\Maps\Constraints

Figure 2-1

sizing purposes, a drainage area of 8.7 acres with 19% impervious cover was used. Potential sources of pollutants in this drainage area are road runoff, parking lot runoff, slope erosion, and the athletic fields, which may contribute excess fertilizers and pesticide to stormwater runoff.

The soil at this site is relatively deep (greater than 10 feet to bedrock, ~5 feet to seasonally high groundwater) and is characterized as sandy loam. This site is within 100 feet from a wetland and is also located in priority and estimated habitat as identified by NHESP.

BHP-4 – Pond Road Drainage

BHP-4 includes a portion of the drainage area to an intermittent stream that flows from the southeast end of the watershed to the northeast corner of the pond. At the intersection of Whitman Road and Pond Road, a 30-inch storm sewer discharges stormwater runoff into the stream. After a field visit, HW determined that since the stream appeared to have a healthy, natural wooded buffer and contributed a relatively minor pollutant source from the majority of the watershed, it would be most efficient to focus any retrofit efforts on the runoff coming from the enclosed storm drainage pipe. The drainage area to the Pond Road storm sewer includes over 45 acres of high volume roadway (Route 111), low- to medium-density residential, commercial institutional (Elementary School), and forest. Seventeen percent of the drainage area is impervious. Potential sources of pollutants in this drainage area are road runoff, parking lot runoff, and residential lawns.

The soil at this site is relatively deep (greater than 10 feet to bedrock, ~5 feet to seasonally high groundwater) and is characterized as sandy loam. A portion of this site is within a Zone I to both Pond Road Rock Well #2 and #5. This site is also located in priority and estimated habitat as identified by NHESP.

BHP-5 – Elementary School Ball Field

The Elementary School ball field drainage area includes one (1) acre of school driveway, parking lot, and athletic field, of which 29% is impervious cover. The site discharges to a 12-inch storm sewer along Route 111 via a partially buried culvert in the rock wall along the field. This storm sewer carries runoff to the Pond Road storm sewer described in BHP-4. This site has shallow depth to bedrock and groundwater (less than 3 feet). Potential sources of pollutants in this drainage area are road runoff, parking lot runoff, and the athletic field.

BHP-6 – Bromfield School Entrance

The Bromfield School entrance drainage area includes 4.4 acres of school driveway, Route 111, and athletic field, of which 30% is impervious cover. Runoff from Route 111 is discharged into a very shallow swale along the north side of the school entrance driveway from an existing 12-inch storm sewer. Stormwater is then directed under the driveway via a 12-inch culvert. Runoff tends to pond on the south side of the driveway before flowing across a ball field to a low point along the rock wall, where it continues to flow down toward the site described under BHP-3. Challenges for this site include a shallow depth to bedrock and groundwater (less than 3 feet) and the heavy use associated with to athletic events and gatherings. Potential sources of pollutants in this drainage area are road runoff and the athletic field.

BHP-7 and BHP-8 – Town Beach
The Town Beach area at the end of Pond Road was identified as a potential retrofit site. After visiting the site, HW determined that this area should be divided into two drainage areas for retrofit sizing. The drainage area for BHP-7 includes 3.4 acres of Pond Road, parking area, and forest, of which 16% is impervious cover. The site currently discharges overland to the north directly into the pond. The soil at this site is relatively deep (greater than 10 feet, ~5 feet to seasonally high groundwater) and is characterized as loamy sand. Potential sources of pollutants in this drainage area are road runoff and parking lot runoff. This site is less than 100 feet from the pond.

The drainage area for BHP-8 includes 3.7 acres of entrance road, loading area, and forest, of which 7% is impervious cover. The site currently discharges overland directly into the pond. Given the elevation of this site, shallow depth to water is expected. Potential sources of pollutants in this drainage area are road runoff. This site is less than 100 feet from the pond.

3.0 STORMWATER MANAGEMENT ASSESSMENT

This stormwater management assessment addresses stormwater runoff as a source of pollutant loading in the Bare Hill Pond watershed and helps to identify potential areas for the installation of stormwater BMPs to reduce the load of stormwater pollutants to the pond. The results of this assessment are then used to recommend site-specific stormwater management implementation projects in key locations in the target subwatersheds. By identifying and prioritizing the most effective retrofit opportunities, the Town and the BHPMC has a reasonable set of specific management options for the grant application. Successful implementation of the identified opportunities is expected to help reduce stormwater runoff pollution and improve overall water quality conditions in the pond.

3.1 Assessment Methodology

The BHPMC initially identified target areas for stormwater retrofits, which were subsequently confirmed by HW. Preliminary drainage areas for these locations were first created through the use of topographic maps, which allow for watershed delineation based on topography alone. However, construction of impervious surfaces, the use of storm drain systems, and grading of land surfaces to accommodate different site designs can alter the overall size and shape of the watershed. Site visits are required for more accurate drainage delineation and to gain a better sense for site issues and constraints. HW investigated potential BMP locations on December 17, 2007, and March 11, 2008. Eight sites were selected from the potential locations based on field assessments of site conditions, physical constraints, and retrofit feasibility. These sites and the proposed retrofits are described in Section 3.3.

3.2 Description of Proposed Best Management Practices

The potential BMPs considered for each of the candidate locations were selected and designed with the goal of improving the overall water quality of the stormwater discharging to the targeted drainage areas of Bare Hill Pond and specifically targeting total phosphorus (TP) and bacteria as priority pollutants for management.

Based on the guidance of Massachusetts Stormwater Management Standards (February, 2008) (hereafter, "Standards"), potential BMPs were sized to capture and treat the **1-inch storm** event runoff from the contributing impervious areas (Water Quality Volume, WQ_v) to the maximum extent practicable since the study area is within a Zone II to a public drinking water source (a so-called "Critical Area"). However, because these are retrofits to an existing stormwater system, site constraints may limit the available area for BMP construction, and the proposed BMPs at certain locations were, therefore, sized smaller than the target WQ_v.

The BMPs proposed for the Bare Hill Pond target drainage areas include bioretention systems, gravel wetlands, dry swales, grass channels, and sediment forebays. These practices collectively are viewed as so-called Low Impact Development (LID) practices and have a proven track record of better pollutant removal capabilities than more conventional practices. Pollutant removal efficiencies and construction costs vary widely for each BMP based upon site conditions. Data from peer-reviewed field studies were compiled to establish estimates of potential pollutant removal efficiencies for each type of BMP. Preliminary cost projections for each type of BMP were created based upon literature information and HW experience. Contingency costs are estimated at 30% of the construction costs. See Appendices A and B for detailed information on pollutant loading, sizing, and cost estimate calculations for this project. The proposed BMPs are described in general below, with more specific descriptions on each retrofit site included in Section 4.

Bioretention System

The bioretention system (also referred to as a "rain garden" or a "biofilter") is a stormwater management practice to manage and treat stormwater runoff using a conditioned soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and adsorption with bio-geochemical processes to remove pollutants. The system consists of an inflow component, a pretreatment element, an overflow structure, a shallow ponding area (less than 9" deep), a surface organic layer of mulch, a planting soil bed, plant materials, and an underdrain system to convey treated runoff to a downstream facility (see Figure 3-1). Pretreatment for bioretention consists of a grass channel, grass filter strip, or a sediment forebay; a gravel diaphragm / stone drop; and a mulch layer. In addition, there are several physical geometry recommendations that should be considered in the layout and design of bioretention systems.

Bioretention systems are cost-effective measures designed to help meet many of the management objectives of watershed protection. Because these practices are proportional to the percentage of impervious area, the cost is relatively constant with drainage area. Unlike retention ponds and constructed stormwater wetlands, whose cost decreases with increasing drainage area, bioretention does not benefit from economies of scale. Planning-level costs for a bioretention facility range from approximately $15 to $25 per square foot. Annual maintenance cost is approximately 5 to 7% of capital construction costs.

Inspections are an integral part of system maintenance. During the six months immediately after construction, bioretention facilities should be inspected at least twice or more following precipitation events of at least 0.5 inch to ensure that the system is functioning properly. Thereafter, inspections should be conducted on an annual basis and after storm events of greater than or equal to the water quality storm event. Minor soil erosion gullies should be repaired when they occur. Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Separation of herbaceous vegetation root stock should occur when over-crowding is observed, or approximately once every three (3) years. The mulch layer should also be replenished (to the original design depth) every other year as directed by inspection reports. The previous mulch layer would be removed, and properly disposed of, or roto-tilled into the soil surface. If at least 50% vegetation coverage is not established after two years, a reinforcement planting should be performed. If the surface of the bioretention system becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the surface should be roto-tilled or cultivated to breakup any hard-packed sediment, and then revegetated.

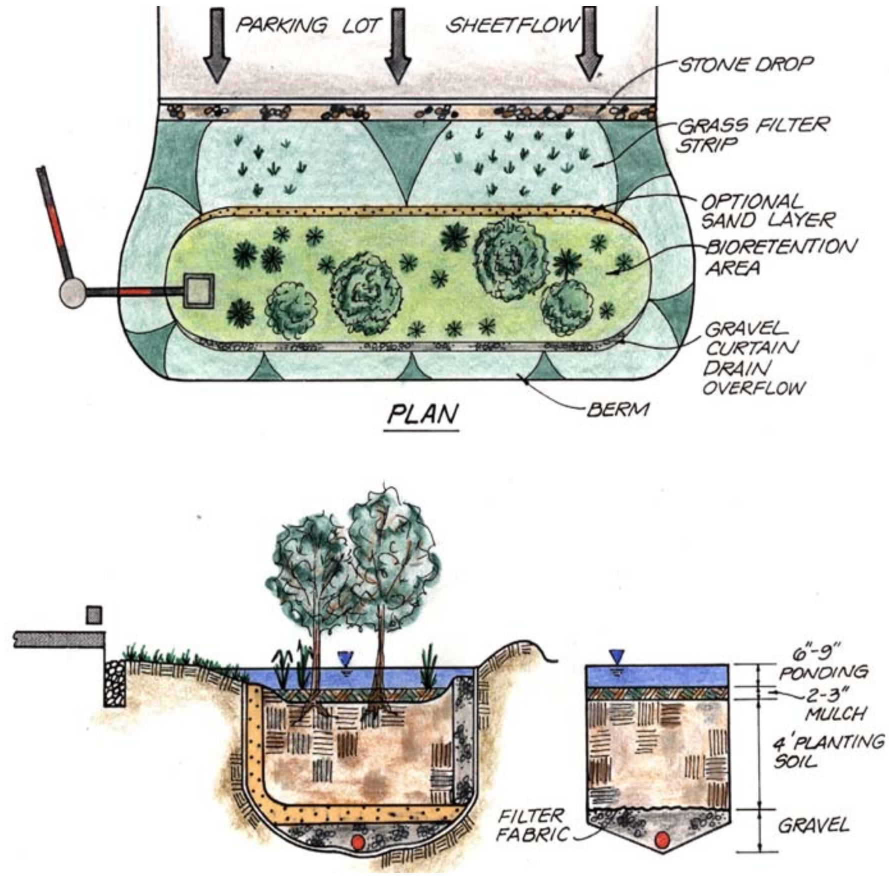


Figure 3-1: Schematic of a Bioretention System (Claytor & Schueler, 1996)

Constructed Wetland

Constructed wetlands are excavated basins with irregular perimeters and undulating bottom contours into which wetland vegetation is purposely placed to enhance pollutant removal from stormwater runoff. The constructed wetland systems used in stormwater management practices are designed to maximize the removal of pollutants from stormwater runoff via several mechanisms: microbial breakdown of pollutants, plant uptake, retention, settling, and adsorption.

There are several designs of constructed wetlands: shallow marsh, extended detention wetland, pond/wetland system, pocket wetland, and gravel wetland. In this study, only one type of wetland is proposed, the gravel wetland, also referred to as a subsurface gravel wetland (see Figure 3-2). This practice is selected based on its ability to meet certain design limitations of proposed retrofit locations and its superior pollutant removal capability.

A site appropriate for a gravel wetland must have an adequate water flow and appropriate underlying soils. Baseflows from the drainage area (based on a minimum drainage area) or groundwater must be sufficient to maintain a shallow pool in the wetland and support the vegetation, including species susceptible to damage during dry periods. Pretreatment for a gravel wetland consists of a forebay sized to treat at least 10% of the required total water quality volume.

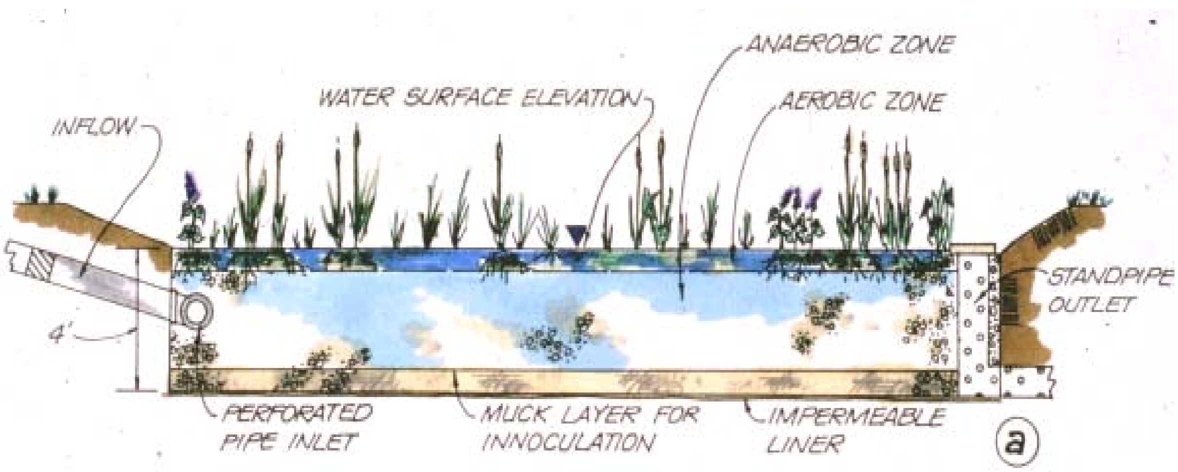


Figure 3-2: Schematic of a Gravel Wetland (CWP, 2002)

Planning-level costs for gravel wetlands are approximately $10-$25 per square foot, depending on the type and size. This includes costs for clearing and grubbing, erosion and sediment control, excavating, grading, staking, and planting.

Like all stormwater management practices, maintenance is required for proper operation of constructed wetlands. Constructed wetlands require routine maintenance such as sediment removal. The majority of sediments should be trapped and removed from the forebay annually. Careful observation of the system over time is required, for the first three years after construction, biannual inspections during both the growing and non-growing season. The vegetative condition should be observed closely to determine the health of the wetland. Vegetative conditions include the types and distribution of dominant wetland plants, the presence and distribution of planted wetland species, and signs that volunteer species are replacing the planted wetland species.

Dry Swale

Dry swales are concave, vegetated conveyance systems that can improve water quality through infiltration and filtering. When designed properly, they can be used to retain and treat stormwater runoff. Dry swales are appropriate in areas where standing water is not desirable such as residential, commercial, industrial areas and highway medians. In dry swales, a prepared soil bed is designed to filter the runoff for water quality (Figure 3-3). Runoff is then collected in an underdrain system and discharged to the downstream drainage system. The design objective for dry swales is to drain down within twenty-four hours of a storm event, which is similar to a bioretention system; except that the pollutant removal is likely to be more limited, since only a grass cover crop is available for nutrient uptake.

A designed swale, such as a dry swale with prepared soil and underdrain piping, has an estimated cost of $15 to $25 per square foot, which is the same range as for a bioretention system. The annual maintenance cost can range from 5 to 7% of the construction cost (SWRPC, 1991).

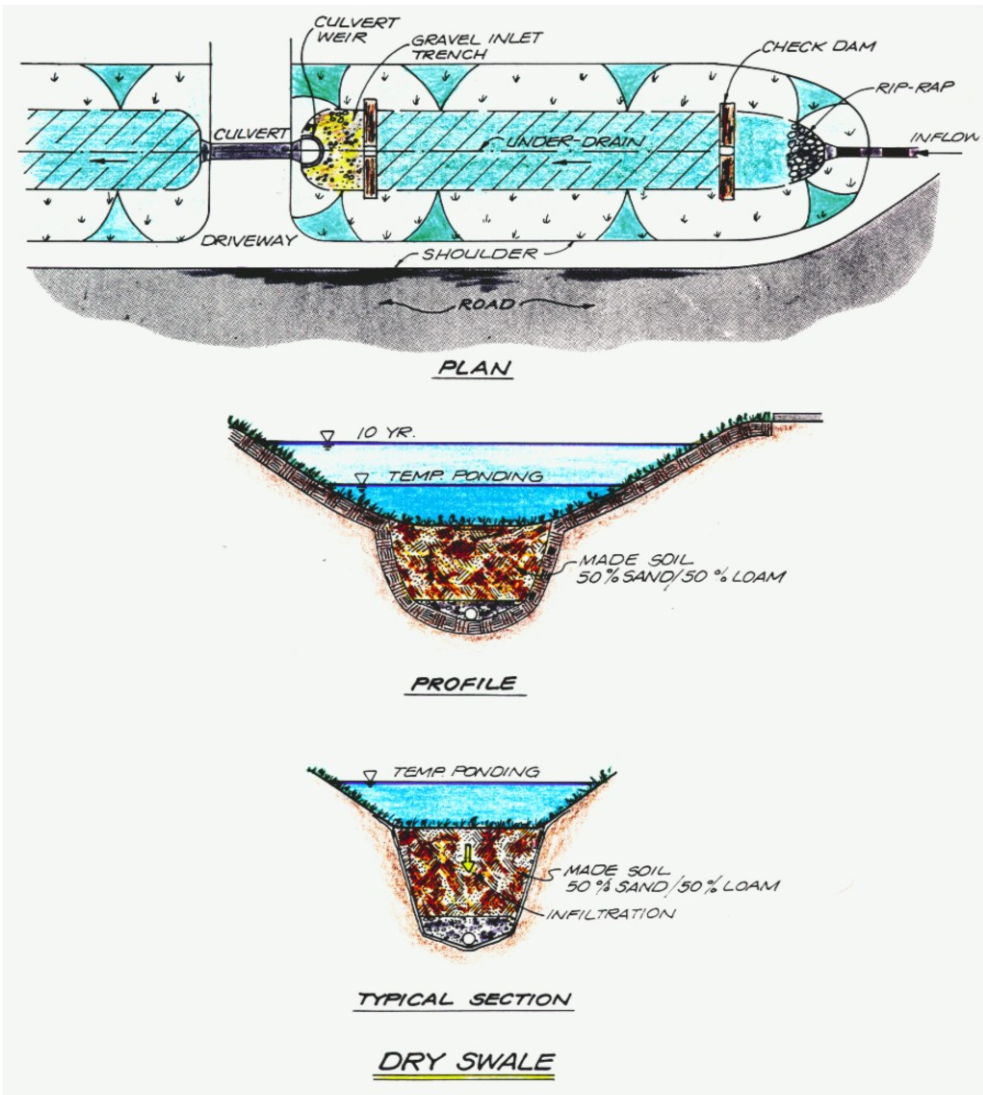


Figure 3-3: Schematic of a Dry Swale (Claytor & Schueler, 1996)

The general design of dry swales takes into consideration the following design criteria (Table 3-1):

Table 3-1: Design Criteria for Dry Swales (Claytor and Schueler, 1996)

Design Criteria	
Bottom Width	2 feet minimum, 8 feet maximum, widths up to 16 feet are allowable if a dividing berm or structure is used
Side Slopes	2:1 maximum, 3:1 or flatter preferred
Longitudinal Slope	1.0% to 2.0% without check dams
Flow Depth and Capacity	Surface storage of water quality volume with a maximum depth of 18 inches for water quality treatment (12 inches average depth). Adequate capacity for 10-year storm with 6 inches of freeboard
Flow Velocity	4.0 fps to 5.0 fps for 2-year storm
Length	Length necessary to drain (dry swale) runoff for 24 hours

The life of dry swales is directly proportional to the maintenance frequency. The maintenance objective for this practice includes keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. The following activities are recommended on an annual basis or as needed:

- Mowing and litter and debris removal
- Stabilization of eroded side slopes and bottom
- Nutrient and pesticide use management
- Dethatching swale bottom and removal of thatching
- Discing or aeration of swale bottom

Every five years, scraping of the channel bottom and removal of sediment to restore original cross section and infiltration rate, and seeding or sodding to restore ground cover are recommended.

Dry swales should be inspected on an annual basis and just after storms of greater than or equal to the water quality storm event. Both the structural and vegetative components should be inspected and repaired. When sediment accumulates to a depth of approximately three (3) inches, it should be removed, and the swale should be reconfigured to its original dimensions. The grass in the dry swale should be mowed at least four (4) times during the growing season. If the surface of the dry swale becomes clogged to the point that standing water is observed in the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded. Trash and debris should be removed and properly disposed.

Grass Channel

Grass drainage channels (also commonly referred to as swales) are proposed for conveyance and pretreatment use (Figure 3-4). Grassed drainage channels accent the natural landscape, break up impervious areas, and are appropriate alternatives to curb and gutter systems. They are best

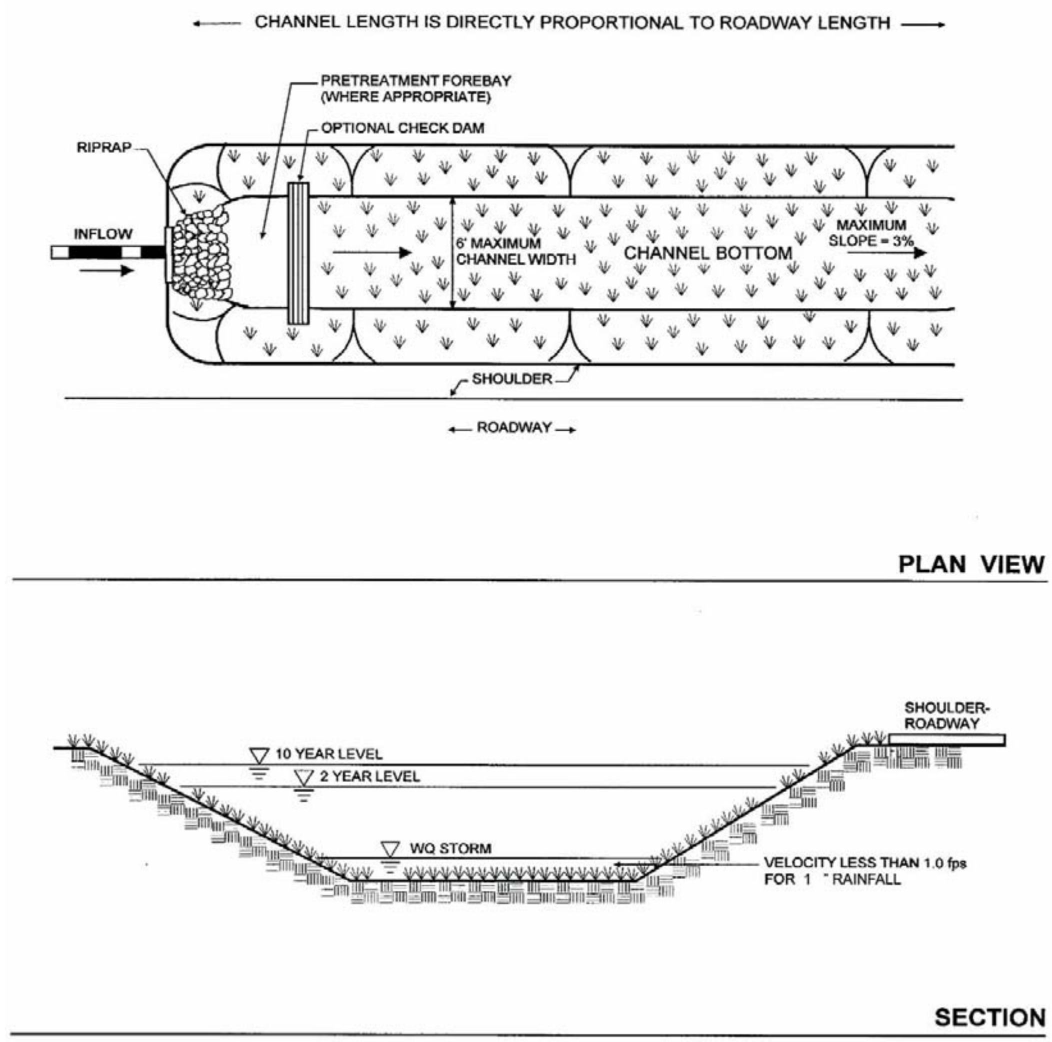


Figure 3-4: Schematic of a Grassed Channel (Vermont Agency of Natural Resources, 2002)

suited to treat runoff from lower density areas and roadways and provide limited infiltration to groundwater. Planning-level costs for a grass channel is approximately $10 per linear foot. The annual maintenance cost can range from 3 to 5% of the construction cost.

The lifetime of grass channels is directly proportional to the maintenance frequency. The maintenance objective for this practice includes preserving or retaining the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. The following activities are recommended on an annual basis or as needed:

- Mowing and litter and debris removal
- Stabilization of eroded side slopes and bottom
- Nutrient and pesticide use management
- Dethatching swale bottom and removal of thatching
- Discing or aeration of swale bottom

Grass channels should be inspected on an annual basis and just after storms of greater than or equal to the water quality storm event. Both the structural and vegetative components should be inspected and repaired. When sediment accumulates to a depth of approximately three (3) inches, it should be removed, and the swale should be reconfigured to its original dimensions. The grass in the channel should be mowed at least two (2) times during the growing season. If the surface of the grass channel becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded. Trash and debris should be removed and properly disposed of.

Sediment Forebay

A sediment forebay is an excavated pit designed to slow incoming stormwater runoff and settle suspended solids. It is primarily used to pretreat stormwater before continuing to the primary water quality and quantity control BMP, typically stormwater basins and wetlands. Frequent cleaning and inspection is essential to the effectiveness of this BMP. Sediment forebays rely primarily on settling for pollutant removal. Pollutants are only removed when the sediments forebays are cleaned out.

The design criteria for sediment forebays should incorporate design features to make maintenance accessible and easy. They should not be any deeper than three (3) to six (6) feet with side slopes not steeper that 3:1. A sediment depth marker makes inspection simple and identifies when sediment removal is due.

The general cost would be similar to stormwater wetlands minus any planting costs. This includes costs for clearing and grubbing, erosion and sediment control, excavating, grading, and staking. Planning-level costs for a sediment forebay is approximately $12 per square foot. Maintenance is essential for proper operation of sediment forebays. Sediment forebays require routine sediment removal annually. Maintenance costs for sediment forebays are estimated at 3% per year of the construction costs.

3.3 Pollutant Loading Assessment

HW used the Simple Method (Schueler, 1987) to estimate total annual pollutant loads for each watershed. It is a method that estimates the pollutant loads from primary land uses. Annual loads were estimated for the primary pollutant of concern, TP, a nutrient that greatly affects the water quality of freshwater systems, as well as for total suspended solids (TSS), the typical "indicator" pollutant used in the Standards. The method uses loading coefficients and impervious cover estimates to calculate annual pollutant loads, and does not account for spatial distribution throughout the watershed.

Load reductions from the proposed structural BMPs for each site, described in Section 4.0, were computed based on the percent of the impervious area captured by the BMPs and the rated BMP pollutant removal efficiency (based on the size and type of each BMP chosen). The total load reduction for each drainage area was calculated by subtracting the reduction potential for the structural BMPs. Detailed results are presented in Appendix A and were used to rank the proposed sites as described below.

4.0 INVESTIGATED SITES AND SELECTED BMP DESCRIPTIONS

The following are descriptions of the eight selected BMP sites identified in the target Bare Hill Pond subwatersheds. Figure 4-1 illustrates the locations of the potential BMP sites. BMPs were chosen to match site characteristics with recommended design criteria.

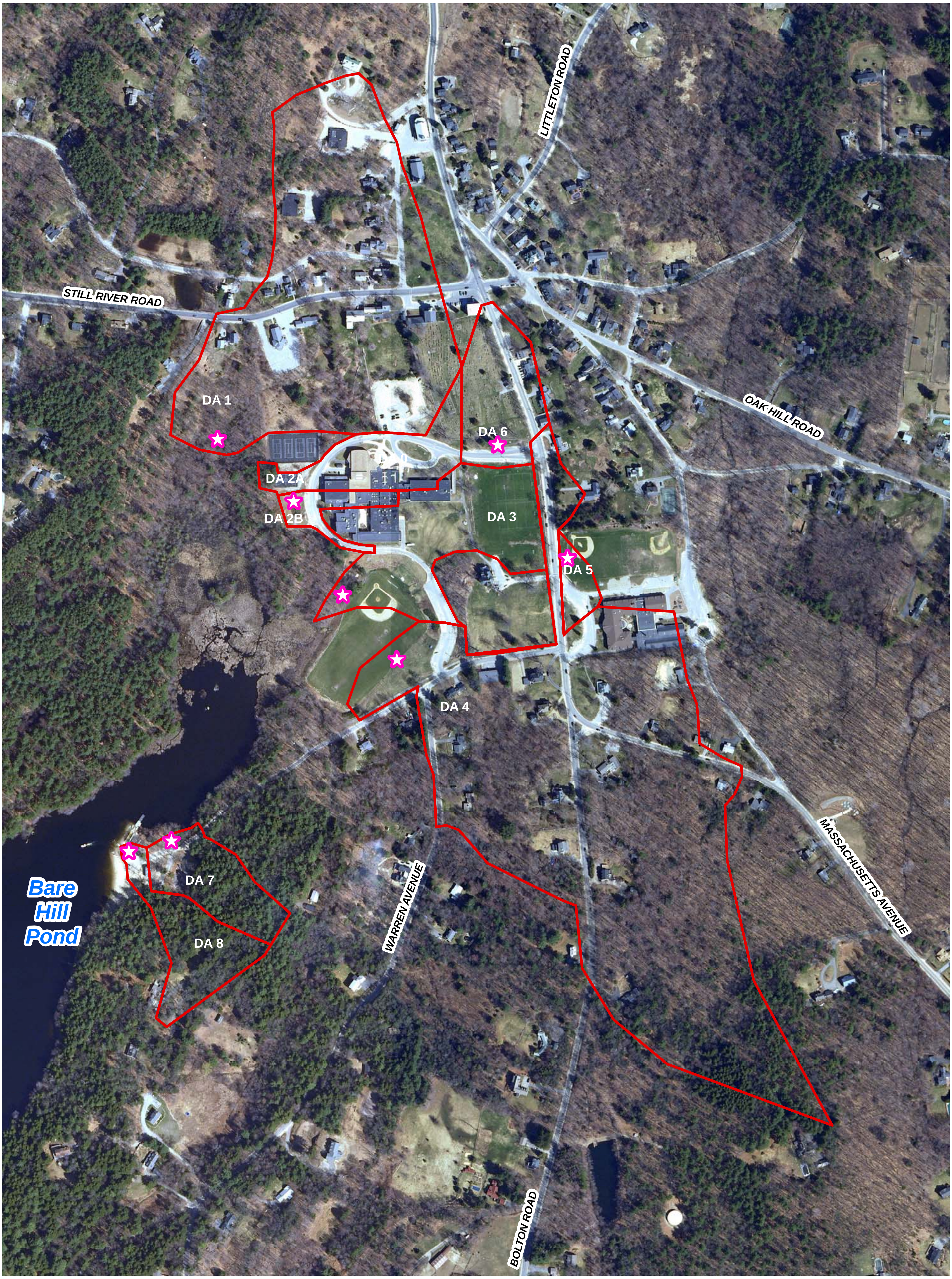
4.1 Site BHP-1 – Intermittent Stream

This site has many challenges for implementing a retrofit BMP, including limited space, proximity to the stream and surrounding wetlands, and poor soils with significant rock outcrops. The proposed concept for this site is to construct a gravel wetland in the clearing alongside the stream created by the gravel path. A sediment forebay would be created in the stream itself just upstream from the culvert, with a V-notch weir to direct runoff from small storm events into the gravel wetland. The gravel wetland will than have an overflow structure that discharges treated runoff back into the stream. Given the space available, the proposed concept will only treat approximately 25% of the target WQv; however, this site will still remove an estimated total phosphorus removal of 3.4 lbs/yr.

The total planning level cost of constructing the facilities is estimated at $125,000, including the sediment forebay, gravel wetland, outlet, and a 30% estimate for contingencies. The design and permitting cost is estimated at $6,600, and the lifetime maintenance cost is estimated at $65,000. The conceptual layout can be found in Appendix C, and typical cross-section of a gravel wetland in Figure 4-3.

4.2 Site BHP-2 – Bromfield School Detention Pond

The Town identified Detention Pond 2 as a potential retrofit site. The pond currently treats the stormwater to some extent, with the Stormceptor units for pretreatment and the shallow, permanent pool that supports wetland vegetation. However, upon field investigation and preliminary modeling in HydroCad, HW determined that a slight modification to the existing pond could significantly and reliably increase treatment capability. First, the existing outlet structure has three orifices – the lowest of which is 18 inches in diameter. This large orifice does not provide adequate detention for small storm events, i.e., the majority of the storm flow coming into the pond immediately flows out. We proposed to restrict the existing orifice down to one (1) inch. Our preliminary model shows that this will increase the detention time of the 1-inch storm from 2.5 hours to over five (5) hours. Second, we propose to add a sediment forebay to the northern inlet, which has the largest drainage area. While the Stormceptor units do remove a portion of the sediment from the stormwater, they are not efficient at removing the fines. The fine material can build up in the pond basin, become resuspended during storm events, and eventually be carried out of the pond. We also propose to augment the existing wetland vegetation to provide additional filtering and uptake of nutrients.



Legend

Drainage Areas

Streams

Proposed BMP Locations

N

400 Feet

Horsley Witten Group
phone: 508-833-6600
www.horsleywitten.com

Drainage Areas and BMP Locations
Bare Hill Pond
Harvard, MA

4/13/08 mw
J:\7143 Bare Hill Pond\GIS\Maps\Overall_Locus

Figure 4-1

The estimated total phosphorus removal from this retrofit is 2.7 lbs/yr. The total planning level cost of constructing the facilities is estimated at $13,000, including the outlet modifications, the sediment forebay, the wetland vegetation, and a 30% estimate for contingencies. The design and permitting cost is estimated at $1,300, and the lifetime maintenance cost is estimated at $4,000. The conceptual layout can be found in Appendix C.

4.3 Site BHP-3 – Bromfield School Ball Field

A main concern for the Bromfield School ball field site is that any potential retrofit practice should not impede the heavy use of this area for athletic events and maintenance activities. The proposed practices include a shallow grass channel to convey stormwater around the edge of the ball field into one or more yard drains. The drainage pipe will carry the runoff to the western edge of the ball field into a diversion manhole (see Figure 4-2). A diversion manhole is proposed to direct only the first one (1) inch of rainfall into a gravel wetland while runoff from larger storms will bypass the gravel wetland and flow directly down into the natural wetlands around Bare Hill Pond. The terrain at the location of the gravel wetland is very steep. As a result, "terraces," or vertical drops created by concrete walls (or similar structural component, such as gabions), will be necessary to accommodate the steep slope while also creating level storage areas for treatment. This concept will treat 100% of the target WQv from the entire drainage area, and the total estimated phosphorus removal is 5.1 lbs/yr.

Figure 4-2 Schematic of a Diversion Manhole

The total planning level cost of constructing the facilities is estimated at $201,000, including the gravel wetland and related infrastructure along the ball field, and a 30% estimate for contingencies. The design and permitting cost is estimated at $18,000, and the lifetime maintenance cost is estimated at $60,000. The conceptual layout can be found in Appendix C and the typical section in Figure 4-3 below.

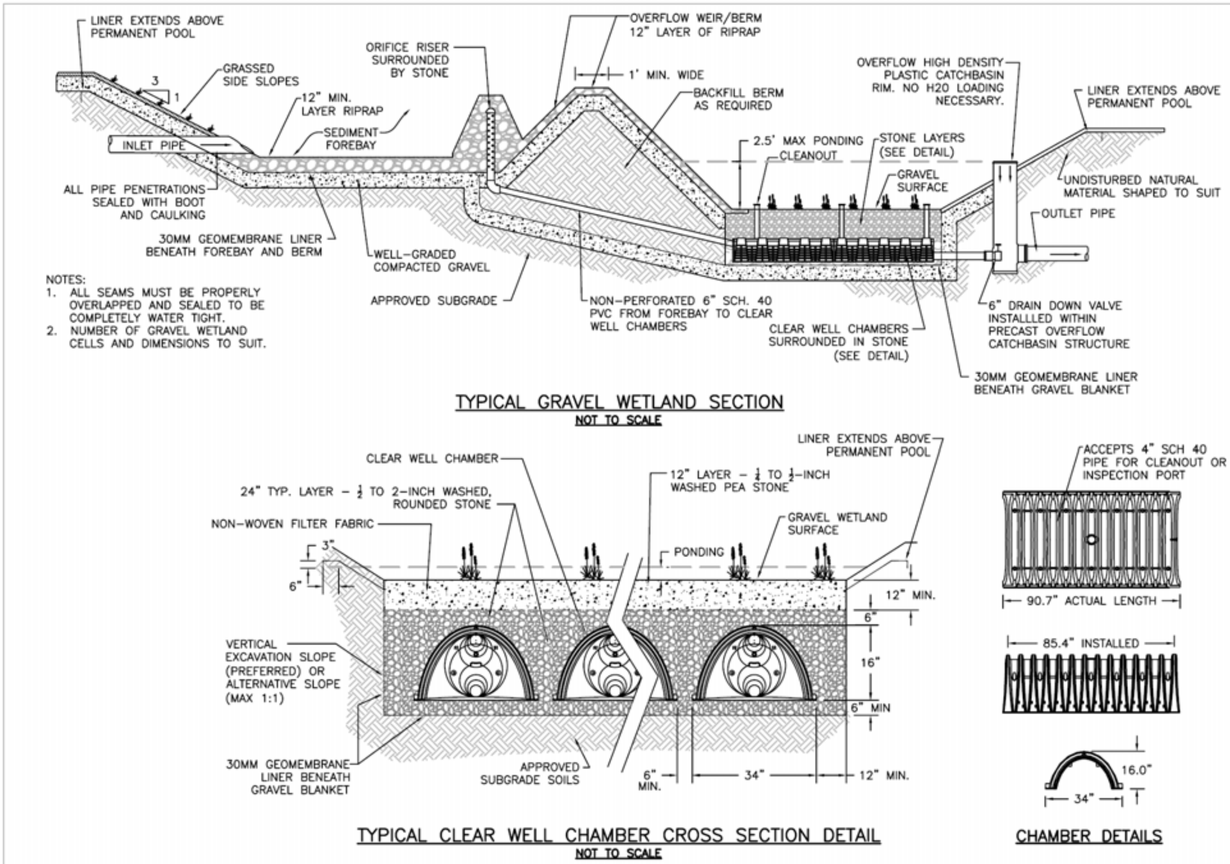


Figure 4-3 Typical Section of Gravel Wetland

4.4 Site BHP-4 – Pond Road Drainage

The proposed concept for this site is to install a diversion manhole on Pond Road just southwest (downstream) from the catchbasin at the intersection with Warren Avenue. This diversion manhole will direct runoff from the one-inch storm event into an oil/grit separator for pretreatment before flowing into a dry swale along the southern edge of the Bromfield School ball field. The stormwater will enter the dry swale at up to 10 different locations via a manifold to help diffuse the runoff and distribute it across a larger length of the swale. The dry swale will have an overflow riprap spillway at the western end near the existing discharge location for the drainage tile from the ball field, but the majority of runoff from larger events will bypass the dry swale entirely in the existing storm sewer along the road. The proposed swale will have a very shallow side slope along the field for the safety of the athletes (see Figure 4-4 for a typical section). Given the large drainage area and space constraints, the proposed concept will treat 50% of the target WQv, but will have an estimated total phosphorus removal of 8.6 lbs/yr.

The total planning level cost of constructing the facilities is estimated at $140,000, including the oil/grit separator, dry swale, and a 30% estimate for contingencies. The design and permitting cost is estimated at $12,300, and the lifetime maintenance cost is estimated at $62,000. The conceptual layout can be found in Appendix C.

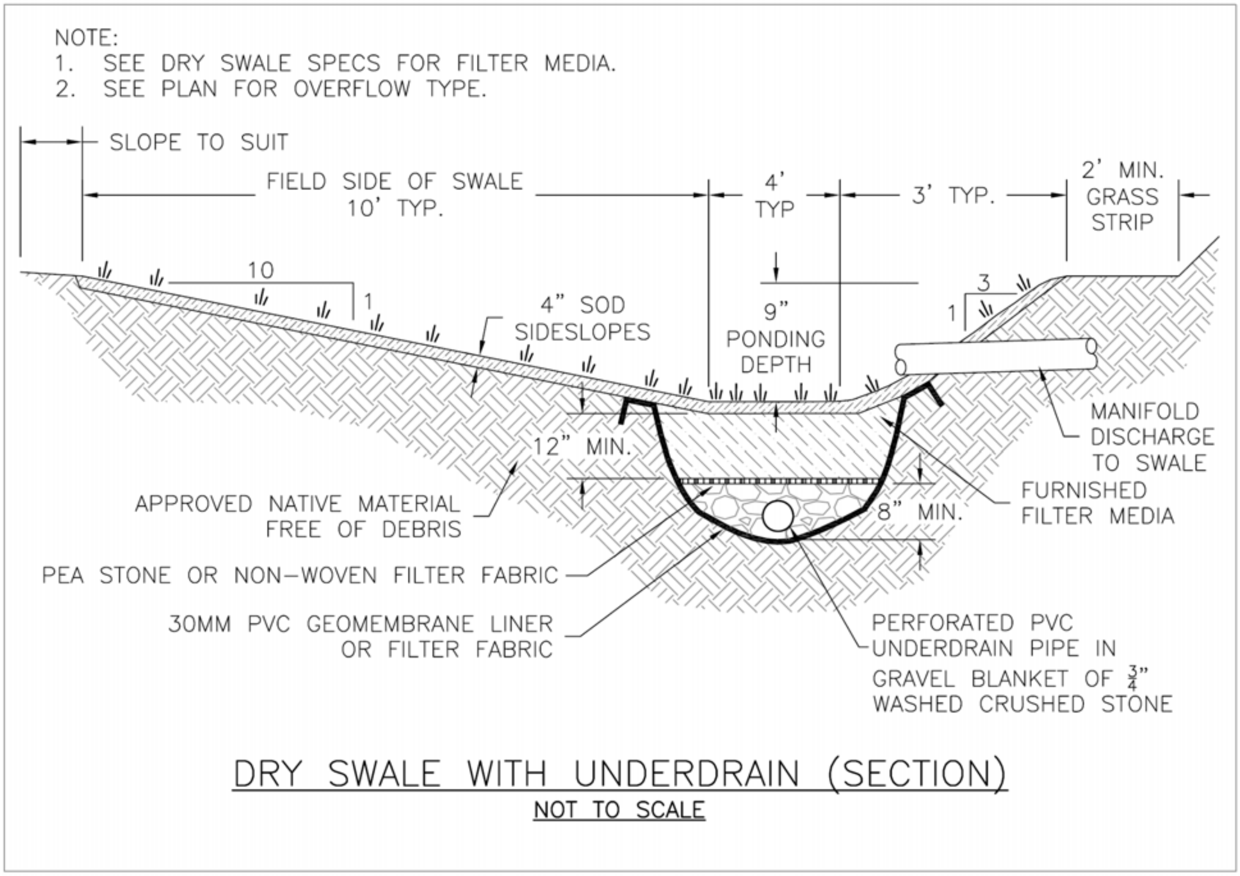


Figure 4-4 Typical Section of a Dry Swale

4.5 Site BHP-5 – Elementary School Ball Field

This site has a very shallow depth to groundwater and bedrock (~2 ft). As a result, the proposed BMP for this site includes a rain garden to treat runoff prior to entering the storm drain system that ultimately flows along Pond Road, as described under site BHP-4. A rain garden is very similar to a bioretention area, but does not include an underdrain system. Given the site constraints, the rain garden will have a very shallow planting bed and will incorporate plants adapted to saturated soil conditions, typical at constructed wetlands. The proposed BMP was sized to treat 100% of the target WQv. The location of this BMP site along a busy athletic field provides a great opportunity for public awareness.

The estimated total phosphorus removal for this retrofit BMP is 0.9 lbs/yr. The total planning level cost of constructing the facilities is estimated at $8,000, including the rain garden and a 30% estimate for contingencies. The design and permitting cost is estimated at $850, and the lifetime maintenance cost is estimated at $8,000. The conceptual layout can be found in Appendix C.

4.6 Site BHP-6 – Bromfield School Entrance

Challenges for this site include a highly used area (school entrance road and athletic field), as well as shallow depth to bedrock and groundwater. The proposed concept for this site is to direct the runoff from the existing 12-inch storm sewer from Route 111 into a linear bioretention area along the north side of the school entrance road. The existing culvert under the entrance road will remain. Stormwater will be conveyed via a grass swale along the edge of the ball field on the south side of the entrance to the existing discharge point along the rock wall. The bioretention area will treat 100% of the target WQv, and the estimated total phosphorus removal is 4.0 lbs/yr. The location of this BMP site provides an opportunity for public awareness.

The total planning level cost of constructing this BMP is estimated at $39,000, including the bioretention area, grass channel, and a 30% estimate for contingencies. The design and permitting cost is estimated at $3,500, and the lifetime maintenance cost is estimated at $30,000. The conceptual layout can be found in Appendix C.

4.7 Site BHP-7 – Town Beach Parking

The proposed BMP for this site is to install a grass swale to pretreat and direct runoff from the entrance road and parking area into a bioretention system. The bioretention system will not be lined to allow for infiltration into the underlying soils, which are characterized as loamy sand. The proposed concept will treat 100% of the target WQv for this drainage area and will have a riprap spillway for discharges from larger storm events into Bare Hill Pond. The estimated total phosphorus removal is 1.9 lbs/yr. The location of this BMP site provides an opportunity for public awareness.

The total planning level cost of constructing this BMP is estimated at $17,000, including the grass channel, bioretention area, and a 30% estimate for contingencies. The design and permitting cost is estimated at $1,700, and the lifetime maintenance cost is estimated at $12,000. The conceptual layout can be found in Appendix C.

4.8 Site BHP-8 – Town Beach Landing

The proposed BMP for this site is to install a four-inch high asphalt diversion berm (speed bump) along the western edge of the boat landing to direct runoff into a sediment forebay and bioretention system. The bioretention facility will not be lined to allow for infiltration into the underlying soils, which are mostly beach sand. The proposed concept will treat 100% of the target WQv for this drainage area and will have a riprap spillway for discharges from larger storm events into Bare Hill Pond. The estimated total phosphorus removal is 1.2 lbs/yr. The location of this BMP site provides an opportunity for public awareness.

The total planning level cost of constructing this BMP is estimated at $16,000, including the speed bump, sediment forebay, bioretention area, and a 30% estimate for contingencies. The design and permitting cost is estimated at $1,700, and the lifetime maintenance cost is estimated at $11,000. The conceptual layout can be found in Appendix C.

5.0 RECOMMENDATIONS

The following table lists the eight proposed BMP retrofit sites in order based on the total phosphorus removal potential, ordered from highest to lowest.

BMP Retrofit Sites	TP Removal (lbs/year)
BHP-4	8.6
BHP-3	5.1
BHP-6	4.0
BHP-1	3.4
BHP-2	2.7
BHP-7	1.9
BHP-8	1.2
BHP-5	0.9

If all projects cannot be implemented at once, the BHPMC may want to consider focusing grant applications and other funding efforts on the retrofit BMPs with the highest TP removal potential. Eventual implementation of all of the identified opportunities will help reduce stormwater runoff pollution and improve overall water quality conditions in the pond.

6.0 REFERENCES

Center for Watershed Protection (CWP), 2007. Urban Stormwater Retrofit Practices, Version 1.0. Ellicott City, MD.

CWP, 2001. The Watershed Treatment Model, Version 3.0. Prepared by Deb Caraco. Ellicott City, MD.

CWP, 2000. The Practice of Watershed Protection: Techniques for Protecting and Restoring Urban Watersheds. Edited by T.R. Schueler and H.K. Holland. Ellicott City, MD.

CWP, 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Prepared for US EPA Office of Science and Technology. Ellicott City, Maryland.

Claytor, R.A. and Schueler, T.R. December 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection (CWP). Ellicott City, Maryland.

ENSR. 1998. Bare Hill Pond Water Quality and Aquatic Plant Evaluation. ENSR Northborough, MA.

Heidorn, M. June 2006. Comprehensive Source Protection Plan: Pond Road and Bolton Road Wells, Harvard, Massachusetts. Mass Rural Water Association. Prepared for the Town of Harvard.

Massachusetts Department of Environmental Protection (MADEP) and Massachusetts Office of Coastal Zone Management (MACZM). 2008. Stormwater Management Handbook. Volumes 1-3.

Massachusetts Department of Environmental Protection. July, 1999. Bare Hill Pond, Harvard, MA. (MA81007) TMDL. DEP, DWM TMDL Report MA81007-1999-001

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C.

Schueler, T. 1992. "Design of Stormwater Wetland System: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region." Metropolitan Washington Council of Governments. Washington, D.C.

Vermont Agency of Natural Resources (VT ANR), 2002. The Vermont Stormwater Management Manual Volume One: Stormwater Treatment Standards. Waterbury, Vermont.

Whitman and Howard. 1987. Diagnostic/Feasibility Study Bare Hill Pond. Harvard, MA. Prepared by Whitman and Howard, Wellesly, MA.

Winer, Rebecca, 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.