Low Impact Development (LID)
As a Watershed Management Tool

New Development and Retrofit Potential

Integrated LID site layouts consist of "Integrated Management Practices" (IMPs) that function as a system to provide water quality controls and runoff peak and volume controls in an attempt to match the pre-development runoff hydrograph for the site. Based on the design approach offered in *Low-Impact Development Design Strategies* (Prince George's County), typical IMPs include:

- Bioretention facilities
- Dry Wells
- Filter/buffer strips
- Grassed and other swales
- Rain barrels
- Cisterns
- Infiltration trenches

Other key concepts that are incorporated into integrated LID designs include:

- Disconnectivity of impervious areas
- Reduction of impervious area
- Minimizing land disturbance
- Site "fingerprinting"
- Increased drainage flow paths
- Open-section roads

In residential areas, fully integrated LID site designs are typically associated with new development projects rather than retrofit projects due to the significant cost that would be incurred by establishing IMPs such as roadside grassed swales (where curb and gutter had been constructed), bioretention facilities, and other infiltration practices in existing neighborhoods. Other factors that would hinder integrated LID implementation in existing neighborhoods would include layout constraints and utility conflicts. Among the IMPs with the greatest retrofit potential in existing residential communities are rain barrels and/or cisterns; however, these practices generally provide runoff peak control only rather than water quality control.

Due to the significant impervious areas that are typical of commercial sites, fully integrated LID designs are not usually feasible without the use of more experimental practices such as "green roofs". Integrated LID potential is greatly reduced as imperviousness begins to exceed 30% (*Low-Impact Development Design Strategies*). The greatest opportunity for LID implementation in commercial areas appears to be with redevelopment projects where detention and/or water quality controls were lacking in the original site construction. In certain cases, LID practices could be designed to accommodate the increase in imperviousness associated with the redevelopment activity.

Since Fairfax County is approximately 90% developed based on the current Comprehensive Plan, there are only limited opportunities for implementing fully integrated LID designs with new construction projects. Furthermore, since the drainage areas to the currently unconstructed regional ponds are approximately 85% developed, there is only a limited potential for fully integrated LID practices in those areas as an alternative to the regional pond construction. Retrofits in the regional pond drainage areas, e.g. via rain barrels, would require extensive public support for the required installations. For instance, a 100-acre regional pond drainage area zoned R-1 would require approximately 600 rain barrels (100 homes X 6 barrels per home) to be installed in order to achieve the comparable detention provided by the regional pond.

The county's Watershed Management Plan process will include an analysis of LID potential in each watershed (new construction and retrofit potential). As a result of this effort, the ability to replace or potentially downsize a given unconstructed regional pond with LID practices will be more clearly defined at a planning level.

LID Infiltration and Filtration Practices

LID Infiltration practices are limited to areas that are suitable based on soil-type, slope, and depth to water table. A separate report by Stormwater Planning Division staff titled, *Identification of Areas Suitable for Implementing Low-impact Development Practices for Promoting Groundwater Recharge*, provides a planning-level indication of areas throughout the County that may be suitable for infiltration practices.

LID Filtration practices can generally be constructed in most site situations. This group of practices incorporates a collection system into the IMP design, typically a perforated pipe, which is then connected to an adjacent storm drainage system. Total runoff volume control is not achieved since infiltration does not occur.

LID Implementation: Fairfax County Ordinance Challenges

Whereas the county's ordinances, primarily the Public Facilities Manual (PFM), do not prohibit LID practices, several additional steps in the plan approval process are required to implement LID designs. Since the additional required approvals for LID practices are not guaranteed, additional risk is introduced into the process for developers. Consequently, the process steers developers towards classic extended dry pond designs as the path of least resistance toward plan approval.

DPWES Industry Letter 01-11, issued on October 2, 2001, (see http://www.co.fairfax.va.us/gov/DPWES/publications/LTI/01-11.pdf) has provided a minor improvement to the process in that certain "innovative" BMP practices from an approved list receive conceptual approval with the corresponding plan rather than requiring a separate approval in advance of the plan. At this time, the "innovative" BMP list consists only of select practices from the Virginia Stormwater Management Handbook, and does not include all of the typical LID IMPs.

To implement a fully integrated LID design, several other major issues arise due to current PFM requirements:

1. There is no approved method in the PFM for quantifying the detention provided with a complete LID site layout. The manual, *Low-Impact Development Design Strategies* (Prince George's County), provides a sound method for quantifying detention (runoff peak control), runoff volume control, and water quality control. Without such an approved method, designers need to derive a method for representing detention calculations on each project.

2. BMP calculations are still required to be depicted in the typical NVRC format. Even if a comprehensive LID design method were used, such as the *Low-Impact Development Design Strategies* method, currently, BMP calculations would also need to be recalculated in accordance with the NVRC format and be depicted on the plan. Whereas, this is not a major issue, it still introduces additional costs to the LID design.

3. The PFM requires that stormwater management facilities be placed on non-residential lots, consequently, a strict interpretation of the PFM would dictate that if IMPs were sited on individual residential lots, they could provide controls for that lot only. With that interpretation, the simplest method of achieving an integrated LID layout would be to site IMPs on small "outlots" or parcels located within a residential lot. Any IMP serving an area offsite to the host lot would need to be maintained by an HOA or the county (if possible based on the type of IMP).

Items 1 and 2 could be remedied by explicitly permitting the use of an existing method for quantifying detention and water quality controls such as the Prince George's County method. This could readily be accomplished via an Industry Letter or by simply adding the Prince George's County manual IMPs and corresponding design methods to the OSDS list of approved innovative BMP's. A survey of submitting engineers and other OSDS customers conducted at the Engineers and Surveyors Institute (ESI) LID class in April 2002, indicated that the vast majority of plan submitters would be more likely to submit integrated LID designs if the county accepted a method (such as the prince George's County method) for quantifying LID detention and water quality controls. The main reason for this support was the elimination of the risk associated with the current need for additional approvals for integrated LID designs as indicated above.

Item 3 above could be resolved by issuing an Industry Letter or by amending the PFM to exclude certain IMPs from the requirement to site stormwater management facilities on non-residential lots.

One last major ordinance-hindrance to integrated LID implementation is that the typical LID roadside swale design does not conform to VDOT standards for roadside ditches. This is related to an overall issue of private or public maintenance of IMPs. Until VDOT would permit such swales in the right-of-way, there are 2 basic methods to achieve an equivalent layout:

1. Swales could be placed along private streets where permitted e.g. in PDH zoning.

2. Swales could be placed outside of the right-of-way for public streets.

Until all the major ordinance issues cited above are adequately addressed, it would be extremely difficult to rely on LID practices as an effective watershed management tool in lieu of regional ponds.

LOW IMPACT DEVELOPMENT
EFFICIENCY, MAINTENANCE AND COST ESTIMATES

This document addresses the efficiency, maintenance, and costs of some of the most widely used Low Impact Development (LID) practices, including bioretention, vegetated swales, vegetative filter strip/buffers, infiltration trenches, rain barrels, and cisterns.

BIORETENTION

Bioretention, also known as rain garden, is a practice to manage and treat stormwater runoff using a conditioned planting soil bed and planting materials to filter stormwater runoff. Runoff is treated by a combination of physical (filtering, adsorption, and volatilization) and biological processes. The ideal facility includes several components, including a pretreatment filter strip (grassed channel) inlet area, a ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow system.

Efficiency: Data on the efficiency of bioretention practices to remove pollutants are limited. Use of available monitoring data to predict bioretention performance is complicated because the data have not been collected with similar methodology, or from similarly designed facilities, or from facilities with similar quality in terms of construction and maintenance. The following table presents a summary of performance monitoring data from selected sites, as well as estimated efficiencies (%) of bioretention facilities to remove pollutants.

Table 1. Projected Pollutant Removal Efficiency for Bioretention

	TSS	TP	TN	TKN	NO3	Cu	Pb	Zn
Beltway Plaza Mall Parking Lot, Greenbelt, MD	-	65	49	52	16	>97	>95	>95
Peppercorn Plaza Parking Lot at Inglewood Center, Landover, MD	-	87	-	67	15	43	70	64
Prince George's County Department of Natural Resources, MD, *estimated*	-	81	43	-	-	-	99	99
Claytor and Schueler, *estimated*	90	65	50	-	80	-	-	-
Federal Highway Administration, *estimated*	75	50	50			70-80		
Virginia Stormwater Management Handbook, *estimated*	-	50-65*	-	-	-	-	-	-

TSS: total suspended solids; **TP**: total phosphorus; **TN**: total nitrogen **TKN**: total Kjeldahl nitrogen; **NO3**, nitrate; **Cu**: copper; **Pb**: lead; **Zn**: zinc

(*): The value credited is 50% when the first 0.5 inch of the storm is detained and 65% when the first 1.0 inch of the storm is detained.

Maintenance: The bioretention area requires routine maintenance, similar to conventional landscaping maintenance, to ensure that the system functions well as a stormwater BMP and remains aesthetically pleasing. Routine inspections of the bioretention facility should be carried out twice during the first year and once a year thereafter. In addition, spot inspections should be done after major storms during the first year. Other maintenance considerations include:

- Soil bed: check soil pH, correct erosion, cultivate unvegetated areas to reduce clogging from fine sediments over time
- Ground cover layer: mulch or replant bare spots annually
- Planting materials: replace dead or severely distressed vegetation, prune periodically
- Inflow/outflow: inspect for clogging, repair eroded pretreatment areas, remove accumulated trash and debris

The following table is an example of a typical maintenance schedule for bioretention installations.

Table 2. Sample Maintenance Schedule for Bioretention Installations*

Description	Method	Frequency	Time of year
Soil:			
Inspect and repair erosion	Visual	Monthly	Year round
Organic Layer:			
Remulch void areas	Manual	As needed	As needed
Remove previous mulch layer before applying new layer (optional)	Manual	Once every two to three years	Spring
Add mulch (optional)	Manual	Once a year	Spring
Plants:			
Remove and replace dead and diseased vegetation considered beyond treatment	Depends on proposed planting specifications	Twice a year	3/15 to 4/30 and 10/1 to 11/30
Treat all diseased trees and shrubs	Mechanical or manual	As needed	Variable, depends on insect or disease infestations
Water plants at the end of each day for 14 consecutive days after planting has been completed	Manual	Immediately after completion of project	N/A
Replace stakes after one year	Manual	Once a year	Spring
Replace deficient stakes or wires	Manual	N/A	As needed
Check for accumulated sediments	Visual	Monthly	Year round

(*): *Virginia Stormwater Management Handbook, Vol. I, 1st. Edition, 1999*

Costs: Bioretention systems are less cost intensive than traditional structural stormwater conveyance systems. In 1999, a bioretention unit measuring 400 square feet and built on individual lots cost about $500 in Prince George's County (EPA, 1999). The estimate includes costs to excavate the site (2-3 feet) and to plant the site with 1-2 trees and 3-5 shrubs. It does not include the cost to planting soil and to install under-drain facilities, which are usually required. Retrofitting a site typically costs more, averaging $6,500 for a 400-square-feet unit. This estimate includes the cost to demolish the existing concrete, asphalt, and structures (e.g., on existing parking lots) and to replace fill material with planting soil (EPA, 1999). In Maryland (Kettering Development), retrofitting a commercial site with 15 bioretention units cost $111,600 ($7,440 per unit).

A literature review of different LID techniques by the Low Impact Development Center of EPA (2000) shows that, in Prince George's County, constructing a bioretention facility costs between $5,000 and $10,000 per acre drained depending on soil type. On average, bioretention facilities might cost between $3 to $15 per square foot of bioretention area, depending on design requirement. Additional savings can be achieved from the decrease in construction costs of stormwater drainpipes and other facilities. For example, bioretention practices reduced the amount of stormwater pipes from 800 feet to 230 feet at a medical office building in Prince George's County, Maryland. This change yielded a saving of $24,000, or 50% of the overall drainage costs for the site (PGC, Department of Environmental Resources, 1993).

VEGETATED SWALES

Swale designs traditionally have been simple drainage grassed channels that primarily transport stormwater runoff away from roadways and right-of-ways. However, grass swales have been modified to improve their hydrologic attributes and their efficiency in removing pollutants. Three types of swales--grass swale (also known a biofiltration swales), dry swale (also known as infiltration swale), and wet swale--are known.

Grass Swales: These provide both quantity control (volume) and quality control by facilitating stormwater infiltration. Grass swales are sometimes provided with under-drains, but usually natural soil is used as the filtration bed. These facilities are reasonably effective in removing many pollutants in urban stormwaters. High performance is generally reported for sediments and particulate trace elements. However, the efficiency in removing nutrients varies significantly, as shown in the following table.

Dry Swales: These provide both quality and quantity control of stormwater runoff. The filter bed consists of a bed of prepared soil on top of installed under-drains. Dry swales remove water rapidly. They allow, for example, the front yard to be more easily mowed. Dry swales are often the preferred open channel in residential settings because they prevent standing water, which usually generates complaints by residents. In terms of efficiency to remove pollutants, dry swales are more effective than grass swales and comparable with wet swales.

Wet Swales: These use residence time and natural growth to reduce peak discharge and treat water before water is discharged to a downstream location. In wet swales, water-tolerant vegetation permanently grows in the retained body of water. This practice is often used in highway design. Wet swales are highly efficient in removing pollutants, except phosphorus.

Efficiency: The ability to remove pollutants varies significantly among the different types of vegetated swales. It also varies for a given type of swale (see the following table). This is mainly due to the fact that the efficiency of an individual facility is a function of time of monitoring (season), length and hydraulic residence time within the swale, design runoff removal rate (what portion of first flush is removed), and what is being monitored (concentration of pollutants or mass loading). But, overall in terms of performance, the data in the following table show that dry swales are the most, and grass swales the least efficient.

Maintenance: Maintenance for swales is minimal (Schueler, 1992). Periodic maintenance for dry or wet swales should primarily focus on removing accumulated materials (sediments, trash, and debris).

Maintenance of dry swales includes steps to ensure vigorous and healthy growth of grass, including periodic mowing to keep grasses at acceptable heights and to minimize growth of successive vegetation.

In wet swales, growth established above the sustained waterline must be maintained.

For both wet and dry swales it is important to avoid use of herbicides and fertilizers. In urban environments, the low-lying nature of swales makes them a likely collector of unsightly litter, which must be removed by hand. It is recommended litter inspections be performed twice a year.

Costs: The costs to install dry and wet swales are moderate and low, respectively. Dry swales are more costly than wet swales because highly permeable soils and underdrain systems must be installed in dry swales. The construction cost per acre served is typically about $1,500 (1996 dollar) based on a nearly flat swale with a 10 feet bottom width, 3:1 side slopes, and a ponding depth of 1 foot. This estimate does not include the cost of real estate, design, and contingencies.

The costs of dry and wet swales can also be inferred from the cost of a traditional grass channel, which typically ranges from $5 to $15 (1996 dollar) per linear foot, depending on local conditions, swale dimensions, and degree of internal storage (FHWA, 1997).

Table 3. Pollutant Removal Performance of Vegetated Swales (%)

Type of swale	Reference	TSS	TP	TN	NO_3	Cu	Pb	Zn	Comments
Grass	Claytor and Schueler (1996)	65	25	15	Neg.	Metals 20 - 50			
Grass	PG Dept. Environmental Resources (2000)	30-65	10-25	0-25	-	-	20-50	20-50	
Grass	Yu and Kaighn (1995)	30	Neg.	-	-	Metals 11			
Grass	City of Austin (1995)	68	43	23	-2	-	-	-	
Grass	Zahid Khan et.al. (1997) **(*)**	83	29	-	-	46	67	30	
Dry	Claytor and Schueler (1996) **(**)**	90	65	50	80	Metals 80 - 90			
Dry	Federal Highway Administration (draft 1997)	80-90	65	50		Metals 80 - 90			
Wet	Claytor and Schueler (1996) **(***)**	80	20	40	50	Metals 80 - 90			
Wet	Federal Highway Administration (draft 1997)	80-90	20	40		Metals 40-70			

* Data are for a 200-feet swale configuration.
** Figures represent the average of three sets of reported monitoring data.
*** Figures represent the average of two reported sets of monitoring data.

FILTER STRIPS

Filter strips, also known as vegetated buffer strips, are evenly sloped vegetated areas that treat stormwater runoff by passing and infiltrating the runoff through a vegetated surface (grass or wooded growth). Water flows in a sheet across the vegetated area and is treated by infiltration into the soil and uptake by plants.

Filter strips are not used to attenuate peak stormwater flows, but they are effective in improving water quality. A filter strip characterized by dense vegetative cover achieves the highest rate of pollutant removal through long flow length, low gradient, and uniform sheet flow. Filter strips are appropriate where there is room for installation. They are well suited to ultra-urban environments because they can be located in medians or along road shoulders. They are also used as pretreatment facilities or outlets for other stormwater practices including bioretention.

Efficiency: Little data are available on the effectiveness of filter strips in removing pollutants from urban stormwater runoff. The existing limited data indicates that efficiency is a function of filter strip length (Yu et al., 1993), slope length and gradient (Wong and McCuen, 1982). For example, moderate to high removal rates were found for a 150-feet-long grass filter strip, but only mediocre pollutant removal was achieved by a 75-feet filter strip, treating urban runoff.

Filter strips provide relatively low rates of pollutant removal and are most effective in reducing total suspended solids (up to 70% removal). They are less effective in decreasing total phosphorus (10%), total nitrogen (30%), and suspended metals (40-50%) (Claytor and Schueler, 1996).

Table 4. Projected Pollutant Removal Efficiency for Filter Strips

Sources	TSS	TP	TN	TKN	NO3	Cu	Pb	Zn
Estimated Pollutant Removal Efficiencies (%)								
(Claytor and Schueler, 1996, FHWA, 1997)	70	10	30			40-50		
(Prince Georges County, MD, Manual, 2000)	20-100	0-60	0-60			20-100	20-100	20-80
Actual Measured Pollutant Removal Efficiencies (%)								
18-foot flow length[1]	27	22			6		2	17
50-foot flow length	67	22			8		18	46
150-foot flow length	68	33			9		20	50

1: Flow length is the distance between the top and the bottom of the filter strip along the slope length.

Maintenance: Maintenance is primarily focused on ensuring vigorous and healthy plant growth, preventing formation of rills and gullies, and removing debris and litter. Inspection is important during the first few years to ensure that the strip becomes adequately established. Once a filter strip is adequately established and is functioning properly, periodic maintenance such as watering, fertilizing, and spot repair may still be necessary.

To increase the functional longevity of a vegetated filter strip, the following practices are recommended:

- Regular removal of accumulated sediments
- Periodic reestablishment of vegetation in eroded areas or areas covered by accumulated sediments
- Periodic weeding of invasive species or weeds
- Periodic pruning of woody vegetation to simulate growth

Costs: Filter strips are low-costs BMPs. The principle costs are those entailed by moving soil, construction, and planting. Construction cost per acre served, in 1995 dollars, is about $2,000 per acre for an area established by hydro-seeding (Schueler, 1992). This does not include real estate, design, and contingency costs. Costs for sodding or planting of woody vegetation are significantly higher.

INFILTRATION TRENCHES

An infiltration trench is an excavated trench that has been lined and backfilled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored, usually over a period of several days, until it infiltrates into the soil. Infiltration trenches are very adaptable BMPs, making them suitable for drainage areas that are less than 10 acres in such areas as ultra-urban sites.

Efficiency: Effectiveness is solely a function of the amount of the stormwater infiltrated into the soil (the only portion of the runoff that is not treated is the portion that bypasses the infiltration trench and does not infiltrate). The projected removal efficiencies of two different designs are shown below (Schueler, 1987).

Table 5. Projected Pollutant Removal Efficiency for Infiltration Trenches

TSS	TP	TN	Metals	Bacteria	Comments
75	50-55	45-55	75-80	75	When the first 0.5" of runoff is captured
90	60-70	55-60	85-90	90	When the first 2.0" of runoff is captured

Maintenance: Without an adequate pretreatment unit to remove sediments, the life expectancy of an infiltration trench might be only 5 years (Schueler, 1992). With proper regular maintenance, however, an infiltration trench may last up to 15 years (Schueler, 1987).

Frequent inspections are required immediately after installation. These can be later decreased to two inspections per year. Inspectors should note the water levels in the trench, clogging of inlets and outlets, and accumulation of sediments in upstream pretreatment units. Immediate failure may occur if sediments are not directed away from the trench area during construction.

Costs: Not available.

RAIN BARRELS AND CISTERNS

Rain barrels are containers generally set at the end of a downspout to capture rainwater running off the roof. They are usually plastic drums.

Cisterns are large water-holding devices usually constructed of concrete, plastic, or steel and used to store larger amount of water compared with rain barrels. Cisterns can be built above or below ground.

Pollutant removal efficiency: Not available

Maintenance: Not an issue

Costs: A 55-gallon plastic barrel, with accessories, costs between $20 and $100.

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MAINTENANCE SERVICE LEVELS

Regional BMP Ponds vs. On-site BMP Ponds

1. GOALS OF THE PROGRAM

- To maintain the County's stormwater control facilities in a manner that best assures that the flood control and pollution treatment aspects remain functional.
- To maximize the environmental benefit of existing stormwater facilities through using and encouraging the use of wet meadow environments, bioremediation, and other types of innovative naturalization techniques.

2. BACKGROUND

In order to protect and conserve the land and water resources of the County, the BOS, in 1972, established a stormwater management (SWM) volume control program to provide for the adequate drainage of storm waters through and from development sites without adverse impact to the land over which the waters flow. In 1982, the County expanded and adopted criteria for stormwater management that required developers to include, along with the quantity control design, water quality treatment controls, or best management practices (BMPs), as a means to protect the Occoquan Reservoir water supply. In 1993, in conformance with the Chesapeake Bay Preservation Act, the County began requiring the installation of BMPs in all watersheds of the County, not just in those that drain into the Occoquan Reservoir.

County policy, as stated in the Public Facilities Manual, is to encourage the use of regional and on-site SWM/BMP facilities to minimize adverse down stream effects. The preferred method of detention is through the use of dry detention ponds. The County accepts maintenance responsibility for these when located in residential developments. The ponds are generally located in County easements on private property.

3. DEFINITIONS

<u>Dry Pond:</u> A dry pond temporarily fills-up with water during a storm but is "dry" most of the time.
<u>Wet Pond:</u> A wet pond has a permanent pool of water.
<u>Regional Pond:</u> A pond with a drainage area that is generally 100 acres or greater.
<u>On-site Pond:</u> A pond with a drainage are that is generally less than 100 acres.

4. CURRENT POND INVENTORY, AS OF AUGUST 2, 2002

County Maintenance
(Total Number of Facilities = 961)

Number of Regional Dry Ponds: 27
Number of Regional Wet Ponds: 1
Number of PL-566 Lakes: 6
Number of On-site Dry Ponds: 916
Number of On-site Wet Ponds: 11

Private Maintenance
(Total Number of Facilities = 629)

Number of Regional Dry Ponds: 6
Number of Regional Wet Ponds: 36
Number of On-site Dry Ponds: 400
Number of On-site Wet Ponds: 187

5. CURRENT INSPECTION CYCLE

County Maintenance

All County maintained SWM/BMP facilities are inspected a minimum of once per year. Approximately 80% of agency work performed in the stormwater management program is identified through this inspection; the remaining 20% is generated through response to citizen complaints and inquiries.

Private Maintenance

All privately maintained SWM/BMP facilities are inspected once every five years.

6. CURRENT COUNTY MAINTENANCE SERVICE LEVELS

Because of the large inventory of SWM/BMP facilities, maintenance is limited to the correction of hazardous conditions and to that essential to keeping the facilities functioning as designed. Depending on the severity of the situation, maintenance may deal with any of the following:

- Small tree and brush removal from DAM embankments and access ways (contract services). On-site facilities are cleared approximately once per year; regional facilities are cleared approximately five times per year); pond floors are allowed to remain natural (e.g., un-cut). It should be noted that, typically, only 60% of the inventory requires such clearing by the County, as the remaining 40% are, typically, cut by the property owners around the facilities.

- Repair or replacement of outlet works
- Dam embankment erosion repair
- Removal of trash, debris, and silt that interferes with function
- Tailing-out of the outfall channel to open up outlet works

Provided below, is a comparison of regional vs. on-site pond maintenance service levels. It should be noted that wet pond maintenance costs exclude dredging. If dredging is performed, the costs of such operations can typically comprise the single most expensive maintenance item associated with wet pond maintenance. Since dredging costs are, in large part, cost-prohibitive for many pond owners, the County does not typically require wet pond dredging---unless sedimentation in a particular pond is causing a drainage or erosion problem upstream. In such instances, though, the dredging required by the County typically entails only that which alleviates the problem. In most cases, dredging does not improve water quality and the environment. In fact, there is strong evidence that seems to indicate that dredging activities can actually be detrimental to the vegetation and organisms living on the pond floor. However, if an owner desires to sustain a wet pond environment, a program of regular, selective dredging should be considered.

Regional Dry Ponds

There are currently 33 regional dry ponds in Fairfax County with an average drainage area of 331 Acres.

Routine Maintenance (Maintenance Required at Least Once Every Five-Years) Items:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Dam Embankment Mowing	5	$ 2,000
Low-flow Cleaning	5	650
Dam Embankment Herbicide Treatment	2	200
Dam Embankment Lime Treatment	0.33*	100
Dam Embankment Fertilization Treatment	0.33*	50
Dam Embankment Power Seeding	0.20**	450
Supplemental/Other Items	1	1,000
Subtotal		$ 4,450

*Once every three-years
**Once Every Five-Years

Non-Routine Maintenance:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Minor Infrastructure Repair and/or Replacement	0.10*	$ 1,500
Major Infrastructure Repair and/or Replacement	0.025**	9,250
Subtotal		$ 10,750

*$150K Once every 10 years
**$370K Once every 40 years

TOTAL		**$ 15,200**

Regional Wet Ponds

There are currently 43 regional wet ponds in Fairfax County with an average drainage area of 611 Acres.

Routine Maintenance (Maintenance Required at Least Once Every Five-Years) Items:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Dam Embankment Mowing	5	$ 2,600
Trashrack Cleaning	5	1,000
Dam Embankment Herbicide Treatment	2	250
Dam Embankment Lime Treatment	0.33*	150
Dam Embankment Fertilization Treatment	0.33*	100
Dam Embankment Power Seeding	0.20**	600
Supplemental (Other) Items	1	2,000
Subtotal		$ 6,700

*Once Every Three-Years
**Once Every Five-Years

Non-Routine Maintenance:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Minor Infrastructure Repair and/or Replacement	0.10*	$ 2,000
Major Infrastructure Repair and/or Replacement	0.025**	12,000
Subtotal		$ 14,000

*$20K Once Every 10-Years
**$480K Once Every 40-Years

TOTAL		**$ 20,700**

Regional Pond Maintenance Summary
(Excludes Dredging and Sediment Removal)

Total Annualized Cost Per Dry Facility: $15,200 (excludes sediment removal)
Total Annualized Cost Per Wet Facility: $20,700 (excludes dredging)
Average Drainage Area Controlled (Dry): 331 Acres (Based on a representative sampling of 20 regional dry ponds)
Average Drainage Area Controlled (Dry): 611 Acres (Based on a representative sampling of 40 regional wet ponds, excluding PL-566 sites)
Total Annualized Cost Per Acre Controlled (Dry): $45 (excludes sediment removal)
Total Annualized Cost Per Acre Controlled (Wet): $34 (excludes dredging)

Regional Pond Maintenance Summary Table
(Includes Dredging and Sediment Removal)

Regional Facility	**Ave Drainage Area (Ac)**	**Annualized Maintenance Cost**		**Annualized Selective Dredging Cost Per Acre Controlled**	**Total Annualized Cost Per Acre Controlled**
		Per Facility	**Per Acre Controlled**		
Dry	331	$15,200	$45	Not Practical[1]	$31
Wet	611	$20,700	$34	$83[2]	$117

Notes
1. As most regional dry ponds are in floodplains and have "mature" natural impoundments, dredging and sediment removal operations are deemed counterproductive to the goals of water quality and habitat protection.
2. $83/Acre is based on 30-yr sedimentation rates in the PL-566 program. This program is comprised of 6 regional wet ponds in the Pohick Creek Watershed. The "average" lake has a drainage area of 1,812 Acres, has a normal pool volume of 189 Acre-Feet, and an average sedimentation rate of 1% of the normal pool volume per year. Based on February 2000 cost data published by the Northern Virginia Planning District Commission, the cost to dredge a wet pond is approximately $47/CY (e.g., dredging at $17/CY + hauling/disposal at $30/CY).

On-Site Dry Ponds

There are currently 1,316 on-site dry ponds in Fairfax County with an average drainage area of 16 Acres.

Routine Maintenance (Maintenance Required at Least Once Every Five-Years) Items:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Dam Embankment Mowing	1	$ 200
Low-flow Cleaning	1	130
Dam Embankment Herbicide Treatment	0	0
Dam Embankment Lime Treatment	0	0
Dam Embankment Fertilization Treatment	0	0
Dam Embankment Power Seeding	0	0
Supplemental (Other) Items	1	1,000
Subtotal		$ 1,330

Non-Routine Maintenance:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Minor Infrastructure Repair and/or Replacement	0.20*	$ 600
Major Infrastructure Repair and/or Replacement	0.05**	3,000
Subtotal		$ 3,600

*$3K Once every 5-Years
*$60K Once every 20-Years

TOTAL		**$ 4,930**

On-Site Wet Ponds

Routine Maintenance (Maintenance Required at Least Once Every Five-Years) Items:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Dam Embankment Mowing	1	$ 250
Trashrack Cleaning	1	300
Dam Embankment Herbicide Treatment	0	0
Dam Embankment Lime Treatment	0	0
Dam Embankment Fertilization Treatment	0	0
Dam Embankment Power Seeding	0	0
Supplemental (Other) Items	1	2,000
Total		$ 2,550

Non-Routine Maintenance:

Item	Frequency (Per Year Per facility)	Annualized Cost Per Facility
Minor Infrastructure Repair and/or Replacement	0.20	$ 800
Major Infrastructure Repair and/or Replacement	0.05)	4,000
Total		$ 4,800

*$4K once every 5-Years
**$80K Once Every 20-Years

TOTAL **$ 7,350**

On-Site Pond Maintenance Summary
(Excludes Dredging and Sediment Removal)

Total Annualized Cost Per Dry Facility: $4,930 (excludes sediment removal)
Total Annualized Cost Per Wet Facility: $7,350 (excludes dredging)
Average Drainage Area Controlled (Dry): 16 Acres (Based on a representative sampling of 50 on-site dry ponds)
Average Drainage Area Controlled (Wet): 29 Acres (Based on a representative sampling of 40 on-site wet ponds)
Total Annualized Cost Per Acre Controlled (Dry): $308 (excludes sediment removal)
Total Annualized Cost Per Acre Controlled (Wet): $253 (excludes dredging)

On-Site Pond Maintenance Summary Table
(Includes Dredging and Sediment Removal)

On-Site Facility	Ave Drainage Area (Ac)	Annualized Maintenance Cost Per Facility	Annualized Maintenance Cost Per Acre Controlled	Annualized Selective Dredging Cost Per Acre Controlled	Total Annualized Cost Per Acre Controlled
Dry	16	$4,930	$308	$30[1]	$338
Wet	29	$7,350	$253	$83[2]	$336

Notes
1. $30/Acre is based on the "average" dry pond with a drainage area of 16 Acres, a water quality ponding volume of 0.6 Acre-Feet, and an average sedimentation rate of 2.5% of the water quality ponding volume per year (e.g., 50% of the BMP capacity is expended every 50-years). Based on recent MSMD data, the cost to excavate and dispose of sediment from a dry pond is approximately $20/CY.
2. $83/Acre is based on the "average" wet pond with a drainage area of 29 Acres, a normal pool volume of 3.2 Acre-Feet, and an average sedimentation rate of 1.0% of the normal pool volume per year. Based on February 2000 cost data published by the Northern Virginia Planning District Commission, the cost to dredge a wet pond is approximately $47/CY (e.g., dredging at $17/CY + hauling/disposal at $30/CY).

7. SUMMARY OF MAINTENANCE SERVICE LEVEL COMPARISON

Based on the cost analysis provided in this report, the maintenance of wet and dry on-site ponds is nearly 11 times as expensive as the maintenance of regional dry ponds and nearly four times as expensive as the maintenance of regional wet ponds. Provided below is a tabulated summary of this data.

Pond Maintenance Summary Table and Unit Cost Comparison
(Includes Dredging and Sediment Removal)

Facility	Ave Drainage Area (Ac)	Annualized Maintenance Cost Per Facility	Annualized Maintenance Cost Per Acre Controlled	Annualized Selective Dredging Cost Per Acre Controlled	Total Annualized Cost Per Acre Controlled	Dry Regional Pond Cost Units
Reg Dry	331	$15,200	$45	n/a	$31	1.0
On-Site Dry	16	$4,930	$308	$30[1]	$338	10.9
Reg Wet	611	$20,700	$34	$83	$117	3.8
On-Site Wet	29	$7,350	$253	$83[2]	$336	10.8

8. PUBLIC VS. PRIVATE MAINTENANCE

Based on a ten-year history of publicly maintained stormwater management pond inspections and a three-year history of privately maintained stormwater management pond inspections, it has been found that the maintenance of the public inventory exceeds that of the private inventory, except in the instance of wet pond dredging. With respect to dredging, the County does not have an active dredging program; however, there are a few privately maintained regional wet ponds that are dredged on a routine basis.

Currently, the Maintenance and Stormwater Management Division (MSMD) is in its fourth year of providing an inspection service to owners of all privately maintained stormwater management facilities in Fairfax County. At present, a detailed break-down of overall totals on safety and functional maintenance deficiencies is not available. As the program is still in its infancy, the primary objective has been to establish a working relationship with the owners and to provide specific advice and guidance on the effective maintenance of stormwater control structures. Even though detailed follow-up to date has been performed on only an as-needed basis, it has been the impression of MSMD that the maintenance suggestions provided have been very well received. The majority of the owners have expressed a desire to incorporate the County's suggestions into their maintenance programs but have indicated that such incorporations will be phased in as funding allocations are expanded to accommodate the increased service levels suggested by the County.

Nonstructural Best Management Practices

Nonstructural Best Management Practices (BMPs) include pollution prevention and pollution control measures that do not require building a structure, or reshaping the landscape. They are (1) land management techniques, such as preservation of open space and sensitive areas, land use controls, encouraging watershed protection during site design, erosion and sediment control, urban reforestation and riparian buffer restoration, and landscaping techniques, (2) public education, volunteer and watershed stewardship measures, such as storm drain stenciling programs, animal waste control programs, lawn and garden care education, and other watershed stewardship activities such as stream monitoring and neighborhood cleanups, and (3) control measures, such as vegetative controls, natural infiltration areas, wetlands, and street sweeping.

Some definitions of nonstructural best management practices (BMPs) include techniques such as rain gardens, which promote bio-retention and bio-infiltration of stormwater runoff. However, for purposes of this discussion, since creating rain gardens usually involves some reshaping of the landscape, they are not included here. Measures such as these are discussed under Low Impact Development techniques. It is important to note, however, that the *act of promoting and encouraging such practices* is an example of a nonstructural BMP.

The benefits of nonstructural BMPs to local and regional water resources are widely acknowledged. They are seen as effective in reducing nonpoint source pollution and improving the quality of stormwater runoff. Scientists and watershed managers recognize their value as part of an integrated nonpoint source pollution prevention program.

However, it has often been the case that nonstructural techniques are overlooked because it is difficult to assign a level of pollutant removed or prevented as a result of their implementation. Reliance on engineering calculations for conventional, structural BMPs to comply with stormwater quality requirements has resulted in a regulatory environment that provides little incentive to investigate nonstructural nonpoint source pollution control approaches. More recently, however, tools are becoming available to allow planners to estimate the amount of pollution prevented or controlled as a result of implementing certain nonstructural BMP techniques, particularly vegetative controls, and to evaluate their potential to complement structural BMP programs.

Pollution Prevention Measures, or source reduction, (1) prevents runoff from occurring and/or prevents the generation of pollution before it enters a storm drain system or stream, and (2) preserves the natural infiltrative capacity of the landscape, through the protection of natural resources by conservation, thus reducing the generation of pollutants and allowing any pollutants generated as a result of land uses to be assimilated without reaching the water environment. Once stormwater is polluted, it is expensive to clean. Therefore, pollution prevention measures are economically and environmentally desirable. The difficulty arises when trying to quantify their effectiveness.

> **Land Use Controls** are any number of regulatory or incentive measures aimed at encouraging patterns of development that produce less, or more readily control, pollution. Examples include purchase of development rights, transfer of development rights,

downzoning, upzoning or overlay zoning, measures to preserve open space and buffer zones near water bodies, and opportunities during redevelopment and infill to accommodate growth without adding more impervious surface.

Watershed Protection during site design involves a series of techniques that minimize erosion during construction, minimize the amount of impervious surface, maximize vegetated areas, and cluster development away from identified sensitive natural resources. Some examples of ways to reduce imperviousness are reducing building footprints, reducing building setbacks, minimizing driveway and parking lot size, reducing street widths, re-examining cul-de-sac design, using pervious materials, incorporating bioretention, and encouraging shared parking.

Reforestation and riparian buffer restoration are opportunities to reduce the amount of nonpoint source pollution entering urban streams. Other benefits include wildlife habitat and recreational opportunities.

Landscaping strategies that preserve the natural infiltrative capacity, conserve water, and keep stormwater onsite reduce the amount of runoff reaching local streams. They also may result in lower maintenance costs. Examples include diverting water from downspouts into planting beds, using pervious paving, incorporating on-site irrigation systems, minimizing turf grass in the landscape, applying mulch, and choosing native plants.

Public education programs are aimed at changing human behavior so as to prevent the generation of nonpoint source pollution. In many cases people are not aware of the cumulative impacts of small acts, or the fact that storm drains lead to streams. Through public education and volunteer measures, people are made aware of how their actions impact water quality. Examples include websites, newsletters, brochures, seminars, workshops, and displays at community events. Often an inter-active watershed model is used to demonstrate how activities on land can affect water quality. Storm drain stenciling programs educate communities about the dangers of dumping anything into storm drains, and explain the proper disposal of used motor oil, anti-freeze, paint, pet waste, excess fertilizer, and litter. As a culminating activity selected inlets are stenciled with a "dumping pollutes" message that will serve as a reminder to the community. Lawn and garden care education programs address those nonpoint source pollutants that result from the improper use and disposal of fertilizers, pesticides and herbicides. Volunteer stream monitoring programs and riparian planting programs encourage watershed stewardship.

Watershed Stewardship is promoted through community education programs, participation in the development of local watershed plans, stream cleanups, tree plantings, and riparian and stream restoration. By understanding and being involved in protection of their local watershed, stakeholders - citizens, homeowner associations, businesses, environmental groups, and local government - can make significant contributions to improved water quality.

Control Measures remove nonpoint source pollution after it has entered the environment. Nonstructural control measures usually rely on strategically placing vegetation to capitalize on their pollution removal capabilities. Control measures are more quantifiable because it may be possible to measure input and output and determine a nonpoint source pollution removal efficiency. The Virginia Stormwater Management Regulations contain suggested phosphorus removal efficiencies for vegetative filter strips, grassed swales, bioretention basins and stormwater wetlands. Some measures, which catch and hold stormwater, have an effect on volume control.

Vegetative controls generally are not sufficient to minimize the adverse effects of urban runoff by themselves and should be considered as valuable components of a comprehensive stormwater management plan. The total volume of detention storage that is required to mitigate the effects of development may be reduced if properly designed and located vegetative controls are used to reduce runoff volumes and pollutant loadings. Even though more of a site may be used in designing such a system, reducing the size of structural devices by preserving or establishing vegetated areas produces a more aesthetically pleasing result, while still achieving desired management and reduction goals. Vegetative controls can be subject to chronic maintenance and nuisance problems, and may not function as intended, if the available space, surface drainage characteristics, soil characteristics, hydrology, climate, and organizational requirements of the site are not taken into careful consideration before design and plant selection. Also, the party responsible for maintenance must be given the tools to properly maintain the BMP over the long term.

In some cases, vegetative controls can function in the landscape as nonstructural alternatives to structural BMPs. The presence of high water table, a variety of unsuitable soils, or other site conditions may render vegetative controls, if they are properly located and designed and maintained, as a more suitable approach to stormwater quality management.

Bioretention is often regarded as a structural BMP as well as a nonstructural BMP. In either case, the technique attempts to mimic the biological and chemical conditions in natural areas and incorporate the benefits provided by biological uptake and activity. They can be natural low areas, or constructed within or next to impervious areas, such as parking lots.

Stormwater wetlands are used as a means of controlling urban pollutants while enhancing urban wildlife habitat. Wetland plants are effective in slowing stormwater runoff, promoting settling of particulate pollutants, and nutrient uptake. Naturally occurring wetlands may be considered nonstructural BMPs. Those that must be constructed may be considered structural BMPs.

Street sweeping, using a wet vacuum or regenerative air vacuum equipment at the correct frequencies, can be effective in removing particulates, which have been deposited on urban street surfaces, before they are picked up by stormwater runoff and carried to nearby streams.

Rain barrels are a measure to catch stormwater close to the source, usually from downspouts, and release it slowly, such as directing it to a nearby garden plot. The volume of stormwater runoff is reduced by the capacity of the rain barrel.

Rooftop gardens are another measure to catch and hold rainwater, reduce imperviousness, and the volume of stormwater runoff.

While this discussion focuses on urban nonstructural BMPs, mention should be made of agricultural nonstructural BMPs that are used in Fairfax County on the many suburban horsekeeping operations. Agricultural BMPs are effective in preventing and reducing nonpoint source pollution in stormwater runoff from these operations, by addressing potential problems from erosion, nutrient management and integrated pest management. Examples include: using cross-fencing to create several smaller pastures and rotating the animals, allowing each pasture to rest and recover; fencing animals out of streams; establishing and maintaining riparian buffers; following an appropriate seeding and fertilization program, based on soil tests; using correct procedures for applying pesticides and herbicides; and properly storing and composting animal waste, as part of an approved nutrient management program.

The primary source of information for this discussion is the *Nonstructural Urban BMP Handbook—A Guide to Nonpoint Source Pollution Prevention and Control through Nonstructural Measures*, 1996, Northern Virginia Planning District Commission.

Other sources include:
Better Backyard—A Citizen's Resource Guide to Beneficial Landscaping and Habitat Restoration in the Chesapeake Bay Watershed, 2001, Chesapeake Bay Program.

Developing Successful Runoff Control Programs for Urbanized Areas, 1994, Northern Virginia Soil and Water Conservation District.

Site Planning for Urban Stream Protection, 1995, by the Center for Watershed Protection, Ellicott City, Maryland.

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