4.0 Horsepen Creek Watershed

The Horsepen Creek Watershed consists of nine watershed management areas (WMAa) as listed below:

1. Cedar Run
2. Frying Pan
3. Indian
4. Lower Horsepen
5. Lower Middle Horsepen
6. Merrybrook
7. Middle Horsepen
8. Stallion
9 Upper Horsepen

WMAs in the Horsepen Creek Watershed are shown in Figure 4.1. As shown in the figure, all of the Stallion WMA is located in Loudoun County and only very small portions of the Lower Horsepen WMA and the Indian WMA are located in Fairfax County. Most of the Merrybrook WMA, the Lower Middle Horsepen WMA and the Middle Horsepen WMA are located in Fairfax County with only small portions of these WMAs located in Loudoun County. Only areas within Fairfax County were evaluated as part of this study; however, information on stormwater structures and stream crossings near the county border was gathered and evaluated based on how it would affect stormwater flows in Fairfax County. The following information is provided for each WMA in the subsequent sections of this chapter:

1. WMA Characteristics
2. Existing and Future Land Use Information
3. Field Reconnaissance and Stream Physical Assessment Information
4. WMA Characterization
5. STEPL Modeling
6. HEC-RAS Modeling
7. Subwatershed Ranking

Table 4.1 illustrates the total area of each WMA, the current impervious conditions and the extent and type of stormwater treatment within each WMA.

Table 4.1 Horsepen Creek Watershed WMA Summaries

WMA Name	Total Area (acres)	Impervious Current Conditions (acres)	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Cedar Run	783	203.7	26%	103.6	20.8	0	658.6
Frying Pan	1,131	338.4	30%	207.2	83	116.4	724.4
Indian	2,067	325.0	16%	No Data for Loudoun County			
Lower	3,190	571	18%	No Data for Loudoun County			
Lower Middle Horsepen	1,186	379.7	32%	1.5*	41.9*	71.9*	1071*
Merrybrook	967	396.2	41%	68.4	0	115.1	783.5
Middle Horsepen	953	215.1	23%	102.2	18.7	9.2	822.9
Stallion	2,394	190.6	8%	No Data for Loudoun County			
Upper Horsepen	1,929	556.4	29%	373.3	56.9	188.4	1310.4
Watershed Totals	**14,600**	**3,176**	**22%**	**856.2**	**221.3**	**501**	**5370.8**

* Treatment only within Fairfax County

Figures for Chapter 4 are provided in the beginning of the chapter and are followed by a detailed discussion of each WMA in Sections 4.1 through Section 4.9. Section 4.10 includes a discussion of SWMM modeling results, including a SWMM Peak Flow Map for the 2-year and 10-year storm event.

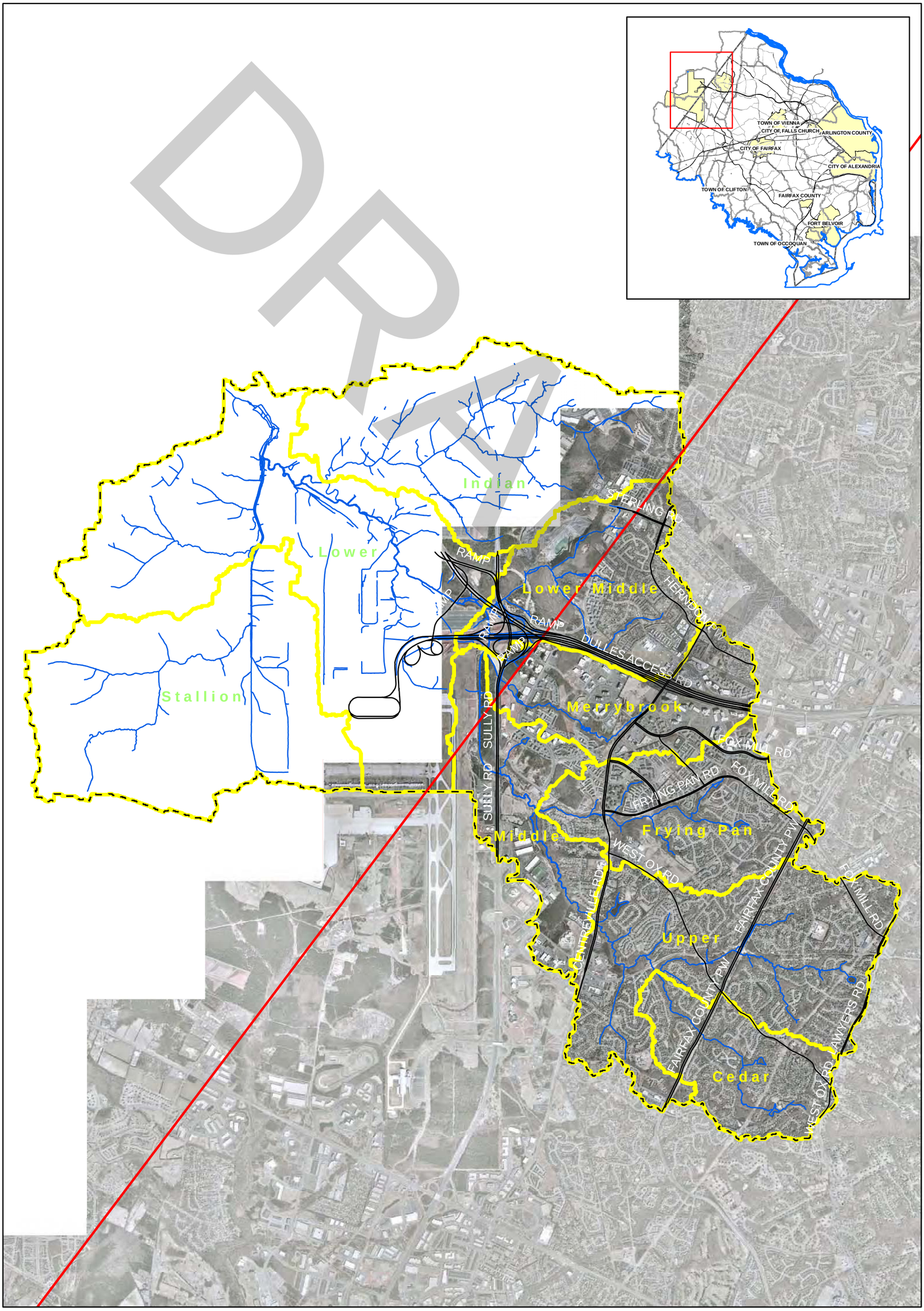

Figure 4.1
Horsepen Creek
Watershed Management Area
Map

Figure 4.2 Existing and Future Land Use Map for Upper Horsepen Creek Watershed

Figure 4.3 Existing and Future Land Use Map for Lower Horsepen Creek Watershed

Figure 4.4 Stream Condition Map for Upper Horsepen Creek Watershed

Figure 4.5 Stream Condition Map for Lower Horsepen Creek Watershed

Figure 4.6 Stormwater Infrastructure Map for Upper Horsepen Creek Watershed

Figure 4.7 Stormwater Infrastructure Map for Lower Horsepen Creek Watershed

Figure 4.8 Total Suspended Solids Map for Horsepen Creek Watershed

Figure 4.9 Total Nitrogen Map for Horsepen Creek Watershed

Figure 4.10 Total Phosphorus Map for Horsepen Creek Watershed

Figure 4.11 Preliminary 100-Year Storm Event for Horsepen Creek Watershed

Figure 4.12 Preliminary Watershed Impact Subwatershed Ranking Map for Horsepen Creek Watershed

Figure 4.13 Preliminary Source Indicator Subwatershed Ranking Map for Horsepen Creek Watershed

4.1 Cedar Run WMA

4.1.1 Cedar Run WMA Characteristics

The Cedar Run WMA is located in the southern tip of the Horsepen Creek Watershed. It is the smallest WMA in the watershed and comprises 783 acres (1.2 square miles). This WMA is almost entirely contained between the Fairfax County Parkway and West Ox Road. A small portion of the WMA extends west beyond the Fairfax County Parkway. See Figure 4.1 for the location of the Cedar Run WMA.

Approximately 2.4 miles of perennial streams are located within the Cedar Run WMA. Most of these streams are in good to fair condition. The streams flow in a northwest direction toward the confluence with Horsepen Creek and travel through primarily medium density residential and open space areas, including parkland along the lower portion of Cedar Run.

4.1.2 Existing and Future Land Use

The Horsepen Creek Watershed, including the Cedar Run WMA, is highly developed. Approximately 65 percent of the WMA is urbanized, consisting primarily of medium and high density residential (49 percent), transportation networks (15 percent) and industrial and institutional (1 percent) land uses, as shown in Table 4.2. Open space is primarily clustered around the stream corridors, and the downstream end of Cedar Run designated as parkland.

Table 4.2 Existing and Future Land Use in Cedar Run WMA

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	3.3	1.2
High Density Residential	0.1	2.1
Medium Density Residential	48.9	48.9
Low Density Residential	7.5	8.1
High Intensity Commercial	0.0	0.0
Low Intensity Commercial	0.0	0.0
Industrial	0.3	0.3
Institutional	0.6	0.6
Open Space	22.4	21.8
Transportation	15.4	15.4
Water	1.4	1.4
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.2 and Figure 4.2 show the expected change in land use as the Cedar Run WMA continues to develop. A slight decrease in open space and estate residential land use is projected with a corresponding increase in high and low density residential areas within the Cedar Run WMA.

4.1.3 Field Reconnaissance

Field reconnaissance was completed within the Cedar Run WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Cedar Run WMA:

1. Evaluated drainage complaints.
2. Evaluated projects proposed by the county.
3. Evaluated existing stormwater facilities.
4. Conducted a neighborhood source assessment.

The results of each of the field reconnaissance surveys are briefly described below:

Drainage Complaints
One hundred and twelve (112) drainage complaints have been documented within the Cedar Run WMA between 2001 and 2006. Of those, 14 representative complaints were chosen for field investigation. The complaints included erosion around stormwater management facilities, streambank erosion and yard flooding.

Proposed County Projects
Based upon past evaluations and reports, multiple stormwater projects have been proposed within the Cedar Run WMA. Field investigations were conducted to determine whether these projects were still viable. The projects included a stream restoration and stabilization project on Cedar Run, the construction of two regional ponds, and the replacement of a culvert under West Ox Road. Field investigations also verified the completion of a culvert replacement project under Ashburton Avenue.

Existing Stormwater Facilities
Ten stormwater management facilities were evaluated within the Cedar Run WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facility. Two of the 10 facilities were found to inadequately provide stormwater management functions. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Neighborhood Source Assessment (NSA)
A representative neighborhood was chosen for a NSA to help identify potential improvement projects throughout the Cedar Run WMA. The chosen neighborhood consisted of single family detached houses on quarter-acre lots. Five stormwater management facilities were identified, including two farm ponds and three dry ponds. The NSA indicated the potential for stormwater management facility retrofit potential and a need for better lawn and landscaping practices.

4.1.4 Cedar Run WMA Characterization

Approximately 2.5 miles of streams were assessed within the Cedar Run WMA to determine the overall stream conditions in the WMA. As shown in Figure 4.4, the majority of stream length assessed has good habitat conditions, with the exception of two small tributaries which have poor habitat conditions. Most of the streams in the Cedar Run WMA are protected by resource

protection areas, as described in Chapter 1. The main stem was designated as protected in 1993, whereas the headwaters were not added until 2003 and 2005. Several erosion areas, pipes, deficient riparian buffers, obstructions and stream crossings were identified during field reconnaissance, although the majority of the problems were considered minor to moderate. One area of deficient riparian buffer was considered severe to extreme, but that area has a very high restoration potential. The main stem of Cedar Run is in Channel Evolution Model Stage 2, which means the channel is experiencing bed erosion and becoming deeper. The headwaters are in Channel Evolution Model Stage 3, which indicates an unstable channel that is experiencing significant bank erosion.

As shown in Figure 4.6, the Cedar Run WMA contains multiple stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network, including dry ponds, wet ponds and farm ponds. Two regional pond projects are being considered for the area. Table 4.3 indicates that stormwater runoff from approximately 16 percent of the area in this WMA is treated, and approximately 84 percent of the area in this WMA is not treated by any means. Stormwater runoff from most of the areas that do receive treatment is treated for quantity only. Approximately 26 percent of the area in this WMA is impervious. Additional stormwater management facilities are needed in the Cedar Run WMA.

Table 4.3 Cedar Run WMA Summary

WMA Name	Total Area (acres)	Impervious Current Conditions (acres)	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Cedar Run	783	203.7	26%	103.6	20.8	0	658.6

4.1.5 STEPL Modeling

The STEPL model was used to estimate nutrient loadings in each subwatershed as described in Section 2.5. Figures 4.8, 4.9, and 4.10. present the results of the STEPL model for total suspended solids, total nitrogen, and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.4 below shows the total pollutant loading to the endpoint of Cedar Run WMA. According to the STEPL model results, the Cedar Run WMA contributes approximately 5 percent of the total suspended solids, 7 percent of the total nitrogen, and 7 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Cedar Run WMA are presented in Table 4.5. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Cedar Run WMA as compared with unit area loads for the entire watershed.

Table 4.4 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Cedar Run	162.0	5,970.55	908.05
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.5 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Cedar Run	0.207	7.625	1.160
WS Totals	**0.205**	**6.069**	**0.894**

4.1.6 HEC-RAS Modeling

HEC-RAS hydraulic modeling was completed for a 100-year storm event in the Cedar Run WMA. Channel flow capacity was analyzed to determine if the 100-year storm event would overflow the channel and flood onto the floodplain. Additionally, the elevation of the flow was determined with reference to the topographic elevations in the stream valley.

As shown in Figure 4.11, a 100-year storm in the Cedar Run WMA resulted in an overflow event with flooding onto the floodplain. The modeling showed that the 100-year stormflow elevation covered the entire floodplain and reached up the valley slope.

Two culverts are located within the Cedar Run WMA. The culverts were modeled to determine if the 100-year storm exceeded their capacity to carry the flow. The modeling shows that one culvert does not carry the 100-year stormflow and water will pond in the culvert and upstream of the culvert structure. The existence of the ponded water will extend the time period of maximum flow through the culvert. When the ponded water is fully drained, the flow elevation will begin to drop. The second culvert does carry the 100-year stormflow.

4.1.7 Cedar Run WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. One subwatershed within the Cedar Run WMA has been identified as a potential problem area. Based upon existing conditions, the condition of the remainder of the WMA is moderate.

The Cedar Run WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. Two of the five subwatersheds within the Cedar Run WMA have been identified as additional problem areas. The remainder of the Cedar Run WMA was ranked as having moderate levels of stressors and pollutant sources.

4.2 Frying Pan WMA

4.2.1 Frying Pan WMA Characteristics

The Frying Pan WMA is located in the central portion of the Horsepen Creek Watershed, and it is bordered on the east by the Sugarland Run Watershed. It is the fourth smallest WMA in the Horsepen Creek Watershed and consists of 1,131 acres (1.8 square miles). The WMA is almost entirely split in half by Frying Pan Road. It is traversed by Centreville Rd on the west and Sunrise Valley Drive on the north. See Figure 4.1 for the location of the Frying Pan WMA.

There are approximately 3.6 miles of perennial streams within the Frying Pan WMA. Most of these streams are in poor condition. The streams flow in a western direction toward the confluence with Horsepen Creek. The streams travel through a combination of low, medium and high density residential and open space areas. The majority of the open space is designated as parkland.

4.2.2 Existing and Future Land Use

Approximately 65 percent of the Frying Pan WMA is urbanized, consisting primarily of high density residential (24 percent), medium density residential (23 percent), institutional (4 percent), and transportation networks (14 percent) land uses, as shown in Table 4.6. The area of open space is significant and is primarily clustered around the stream corridors and the area between Frying Pan Road and West Ox Road, which is also designated as parkland.

Table 4.6 and Figure 4.2, show the expected change in land use as the Frying Pan WMA continues to develop. A slight decrease in low density residential, institutional and open space land use, with a corresponding increase in high and medium density residential, high and low intensity commercial and industrial areas is projected within the Frying Pan WMA.

Table 4.6 Existing and Future Land Use in Frying Pan WMA

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	1.0	1.0
High Density Residential	24.4	26.8
Medium Density Residential	22.7	23.2
Low Density Residential	5.6	5.5
High Intensity Commercial	0.1	0.2
Low Intensity Commercial	0.7	0.8
Industrial	0.0	0.6
Institutional	4.3	4.1
Open Space	26.0	22.8
Transportation	14.3	14.3
Water	0.7	0.7
Total	100	100

Source: Fairfax County GIS, 2008

4.2.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was completed within the Frying Pan WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Cedar Run WMA:

1. Evaluated drainage complaints.
2. Reviewed on-site septic areas.
3. Documented new construction.
4. Evaluated projects proposed by the county.
5. Evaluated existing stormwater facilities.
6. Conducted neighborhood source assessments.
7. Conducted hot spot investigations.

The results of each of the field reconnaissance surveys are briefly described below.

Drainage Complaints

One hundred and eight (108) drainage complaints have been documented within the Frying Pan WMA between 2001 and 2003. Of those, two representative complaints were chosen for field investigation. The complaints included yard flooding and a stormwater infrastructure problem.

On-Site Septic

Portions of the Horsepen Creek watershed still use on-site septic systems. Properties using on-site systems were chosen for field reconnaissance if problems were noted in the area. One on-site septic area was visited, although no problems were noted.

New Construction

To document areas of growth or re-growth within the watershed, new construction areas were identified for field reconnaissance. Three new constructions areas were field verified including a new church and two apartment buildings.

Proposed County Projects

Based upon past evaluations and reports, multiple stormwater projects have been proposed within the Frying Pan WMA. Field investigations were conducted to determine whether these projects were still viable. Field investigations verified the completion of a culvert replacement project under Centreville Road, a road raising project along a portion of the Frying Pan Branch, a culvert replacement project under Monroe Street and the construction of the Sycamore Lakes regional pond.

Existing Stormwater Facilities

Seventeen (17) stormwater management facilities were evaluated within the Frying Pan WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facility. Four of the 17 facilities were found to not exist, and one was found to not provide stormwater management functions. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Neighborhood Source Assessment (NSA)

Four representative neighborhoods were chosen for a NSA to help identify potential improvement projects throughout the Frying Pan WMA. Three of the chosen neighborhoods consisted of single-family detached houses on lot sizes ranging from less than a quarter-acre to a half-acre. The fourth was a multi-family townhouse complex. The neighborhood conditions, as well as the stormwater management facilities, were evaluated. The NSAs indicated the potential for stormwater management facility retrofit and a need for better lawn and landscaping practices.

Hot Spot Investigation (HSI)

A representative facility with the potential to generate concentrated stormwater pollution was chosen within the Frying Pan WMA for the HSI. An investigation was conducted of the facility and the corresponding property to identify sources of pollution. A school was targeted for the HSI within the Frying Pan WMA, which was identified as a potential hotspot. This indicated the need for future education efforts and the need for a review of the stormwater pollution prevention plan.

4.2.4 Frying Pan WMA Characterization

Approximately 4.4 miles of streams were assessed within the Frying Pan WMA to determine the overall stream conditions in the WMA. As shown in Figure 4.4, the majority of the main stem of the Frying Pan Branch has poor to very poor habitat conditions. One exception is a small section of stream near the intersection of Centreville Road and Frying Pan Road which has excellent habitat conditions. The tributaries have good to fair habitat conditions, with the exception of the small tributary downstream of Centreville Road which has poor to very poor habitat conditions. Most of the streams in the Frying Pan WMA are protected by the resource protection area, as described in Chapter 1. The main stem was designated as protected in 1993, whereas the

headwaters were not added until 2003 and 2005. Several pipes, ditches, deficient riparian buffer areas, obstructions and stream crossings were identified during field reconnaissance, although the majority of the problems were considered minor to moderate. A few areas of deficient riparian buffer were considered moderate to severe; however, the restoration potential for these areas is considered low. The surveyed channels in this WMA are in Channel Evolution Model Stage 3. This indicates an unstable channel that is experiencing significant bank erosion.

As shown in Figure 4.6, the Frying Pan WMA contains multiple stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network. These facilities include dry ponds, wet ponds and farm ponds. A regional pond project has been constructed in the headwaters of the Frying Pan WMA, near Monroe Street. Table 4.7 indicates that stormwater runoff from approximately 36 percent of the area in this WMA is treated, and approximately 64 percent of the area in this WMA is not treated by any means. Stormwater runoff from the areas that do receive treatment is treated for both quantity and water quality. Approximately 30 percent of the area in this WMA is impervious. Additional stormwater management facilities are needed in the Frying Pan WMA to control and treat stormwater is this WMA.

Table 4.7 Frying Pan WMA Summary

WMA Name	Total Area (acres)	Impervious Current Condition	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Frying Pan	1,131	338.4	30%	207.2	83	116.4	724.4

4.2.5 STEPL Modeling

The STEPL model was used to estimate nutrient loadings in each subwatershed as described in Section 2.5. Figures 4.8, 4.9, and 4.10 present the results of the STEPL model, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.8 shows the total pollutant loading to the endpoint of Frying Pan WMA. According to the STEPL model results, the Frying Pan WMA contributes approximately 7 percent of the total suspended solids, 10 percent of the total nitrogen, and 10 percent of the total phosphorous annual loads to the Sugarland Watershed. Pollutant loadings normalized to the acres within the drainage area of Frying Pan WMA are presented in Table 4.9. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Frying Pan WMA as compared with unit area loads for the entire watershed.

Table 4.8 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Frying Pan	208.6	8,484.30	1,246.75
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.9 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Frying Pan	0.184	7.502	1.102
WS Totals	**0.205**	**6.069**	**0.894**

4.2.6 HEC-RAS Modeling

HEC-RAS hydraulic modeling was completed for a 100-year storm event in the Frying Pan WMA. Channel flow capacity was analyzed to determine if the 100-year storm event would overflow the channel and flood onto the floodplain. Additionally, the elevation of the flow was determined with reference to the topographic elevations in the stream valley.

As shown in Figure 4.11, a 100-year storm in the Frying Pan WMA resulted in an overflow event with flooding onto the floodplain. The modeling showed that the 100-year stormflow elevation covered the entire floodplain and reached up the valley slope.

One culvert is located within the Frying Pan WMA. This culvert was modeled to determine if the 100-year storm exceeded the capacity of the culvert to carry the flow. The modeling shows that the culvert does not carry the 100-year stormflow and water will pond upstream of the culvert structure. The existence of the ponded water will extend the time period of maximum flow through the culvert. When the ponded water is fully drained, the flow elevation will begin to drop.

4.2.7 Frying Pan WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. No subwatersheds within the Frying Pan WMA have been identified as a potential problem area. Based upon existing conditions, the remainder of the WMA is in fair to moderate condition.

The Frying Pan WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. One subwatershed within the Frying Pan WMA has been identified as additional problem areas. The remainder of the Frying Pan WMA was ranked as having moderate levels of stressors and pollutant sources.

4.3 Indian WMA

4.3.1 Indian WMA Characteristics

The Indian WMA is the northern border of the Horsepen Creek Watershed and is located almost entirely within Loudoun County. It is the third largest WMA in the Horsepen Creek Watershed and consists of 2,066 acres (3.2 square miles). Only 5.3 acres of the Indian WMA are located in Fairfax County. The WMA is bisected by Sully Road and is bordered on the west by the Dulles Greenway. See Figure 4.1 for the location of the Indian WMA.

There are approximately 4.5 miles of perennial streams within the Indian WMA. These streams flow in a western direction toward the confluence with Horsepen Creek. The streams flow through a combination of low and medium density residential and open space areas.

4.3.2 Existing and Future Land Use

The Indian WMA is partially urbanized, consisting of primarily open space (50 percent), medium density residential (24 percent) and low density residential (18 percent) land uses, as shown in Table 4.10. The open space land use is clustered throughout the Indian WMA.

Table 4.10 Existing and Future Land Use in Indian WMA

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	0.0	0.0
High Density Residential	5.8	5.8
Medium Density Residential	24.5	24.5
Low Density Residential	18.2	18.2
High Intensity Commercial	0.0	0.0
Low Intensity Commercial	0.0	0.0
Industrial	0.0	0.0
Institutional	0.0	0.0
Open Space	50.0	50.0
Transportation	0.4	0.4
Water	1.1	1.1
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.10 and Figure 4.3 show that no change in land use is expected within the Indian WMA.

4.3.3 Field Reconnaissance and Stream Physical Assessment

No field reconnaissance was completed for the Indian WMA since all but 5.3 acres of the total 2,066 acres of the WMA are located in Loudoun County.

4.3.4 Indian WMA Characterization

No stream condition information is available or has been collected for the Indian WMA since most of the WMA is located in Loudoun County. The current stormwater treatment types for the Indian WMA are unknown. No existing stormwater facilities are currently shown on the Stormwater Infrastructure Map for this area.

4.3.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen, and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.11 shows the total pollutant loading to the endpoint of Indian WMA. According to the STEPL model results, the Indian WMA contributes approximately 10 percent of the total suspended solids, 11 percent of the total nitrogen, and 11 percent of the total phosphorous annual loads to the Sugarland Watershed. Pollutant loadings normalized to the acres within the drainage area of Indian WMA are presented in Table 4.12. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Indian WMA as compared with unit area loads for the entire watershed.

Table 4.11 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Indian	292.8	9,309.71	1,406.42
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.12 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/yr)	Total Nitrogen (pounds/acre/yr)	Total Phosphorus (pounds/acre/yr)
Indian	0.142	4.506	0.681
WS Totals	**0.205**	**6.069**	**0.894**

4.3.6 HEC-RAS Modeling

The Indian WMA was not modeled in HEC-RAS because most of the WMA is located in Loudoun County.

4.3.7 Indian WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. Only two subwatersheds within the Fairfax County portion of the Indian WMA were scored. No subwatersheds within the Indian WMA have been identified as potential problem areas. Based upon existing conditions, the remainder of the WMA is in fair condition.

The Indian WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. No additional subwatersheds within the Indian WMA have been identified as additional problem areas. The remainder of the Indian WMA was ranked as having low levels of stressors and pollutant sources.

4.4 Lower Horsepen WMA

4.4.1 Lower Horsepen WMA Characteristics

The Lower Horsepen WMA is located in the northwestern portion of the Horsepen Creek Watershed. The bottom right hand corner of the Lower Horsepen WMA is located in Fairfax County and the remaining portion of the WMA is located in Loudoun County. It is the largest WMA in the watershed and consists of 3,189 acres (5.0 square miles). The WMA is bordered to the north by the Dulles Greenway. Only 20.6 acres (less than 1 percent) of this WMA are located in Fairfax County. See Figure 4.1 for the location of the Lower Horsepen WMA.

There are approximately 7.0 miles of perennial streams within the Lower Horsepen WMA. These streams flow north and northwest toward the confluence with Horsepen Creek. The streams flow through primarily industrial and open space areas, including portions of the Dulles International Airport.

4.4.2 Existing and Future Land Use

Approximately 44 percent of the Lower Horsepen WMA is urbanized as shown in Table 4.3. The largest land use type in the WMA is open space which comprises over 52 percent of the area. The large industrial area (34.5 percent) in the WMA is primarily comprised of the Dulles International Airport.

Table 4.13 Existing and Future Land Use in Lower Horsepen WMA

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	0.0	0.0
High Density Residential	0.5	0.5
Medium Density Residential	2.2	2.2
Low Density Residential	4.2	4.2
High Intensity Commercial	0.0	0.0
Low Intensity Commercial	0.0	0.0
Industrial	34.5	34.5
Institutional	0.0	0.0
Open Space	52.6	52.6
Transportation	2.3	2.3
Water	3.7	3.7
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.13 and Figure 4.3 indicate that no change in land use is expected within the Lower Horsepen WMA.

4.4.3 Field Reconnaissance and Stream Physical Assessment

Only 20.6 acres of the total 3,189 acres in the Lower Horsepen WMA are located in Fairfax County; therefore, no field reconnaissance was conducted for this area.

4.4.4 Lower Horsepen WMA Characterization

Almost 100 percent of the Lower Horsepen WMA lies outside Fairfax County. Therefore, no stream condition information is available or has been collected for the Lower Horsepen WMA.

The current stormwater treatment types for the Lower Horsepen WMA are unknown, as most of the watershed is located in Loudoun County. Approximately 18 percent of this WMA is impervious, and no information is known about the stormwater treatment facilities in this WMA.

4.4.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen, and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.14 shows the total pollutant loading to the endpoint of Lower WMA. According to the STEPL model results, the Lower Horsepen WMA contributes approximately 30 percent of the total suspended solids, 20 percent of the total nitrogen, and 20 percent of the total phosphorous annual loads to the Sugarland Watershed. Pollutant loadings normalized to the acres within the drainage area of Lower Horsepen WMA are presented in Table 4.15. The values in this table indicate the total nutrient and sediment load that results from

stormwater runoff over one acre of Lower Horsepen WMA as compared with unit area loads for the entire watershed.

Table 4.14 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Lower	864.0	17,946.98	2,543.35
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.15 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Lower	0.271	5.628	0.798
WS Totals	**0.205**	**6.069**	**0.894**

4.4.6 HEC-RAS Modeling

Because the Lower WMA is almost entirely located within Loudoun County, the WMA was not modeled in HEC-RAS.

4.4.7 Lower Horsepen WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. Only one subwatershed within the Lower Horsepen WMA was scored, and it was not considered to be a potential problem area. Based upon existing conditions, the condition of the remainder of the WMA is moderate.

The Lower Horsepen WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. One subwatershed in the WMA was scored and it was not considered to be an additional problem area.

4.5 Lower Middle Horsepen WMA

4.5.1 Lower Middle Horsepen WMA Characteristics

The Lower Middle Horsepen WMA is located in the central portion of the Horsepen Creek Watershed and bordered is on the east by Sugarland Run Watershed. Approximately one half of this WMA is located in Fairfax County and the other half is located in Loudoun County. The Lower Middle Horsepen WMA is comprised of 1,188 acres (1.9 square miles). The WMA is bordered on the south by the Dulles Access Road and bordered on the northeast by the Herndon Parkway. See Figure 4.1 for the location of the Lower Middle Sugarland WMA.

There are approximately 3.4 miles of perennial streams within the Lower Middle Horsepen WMA. The streams flow in a western direction toward the confluence with Horsepen Creek. The stream flows through a combination of low, medium and high density residential and open space areas.

4.5.2 Existing and Future Land Use

Approximately 61 percent of the Lower Middle Horsepen WMA is urbanized, consisting primarily of medium and high density residential (36 percent), commercial and industrial (4 acres), and transportation networks (21 percent) land uses, as shown in Table 4.16. This WMA is comprised of almost 30 percent open space. A portion of open space has been designated as parkland between the Dulles Access Road and Parcher Avenue.

Table 4.16 Existing and Future Land Use

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	0.5	0.3
High Density Residential	16.8	16.9
Medium Density Residential	19.4	19.4
Low Density Residential	3.9	3.9
High Intensity Commercial	1.0	2.5
Low Intensity Commercial	2.1	1.4
Industrial	1.2	1.2
Institutional	2.1	3.4
Open Space	29.9	27.8
Transportation	21.1	21.1
Water	1.9	1.9
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.16 and Figure 4.3 show the expected change in land use as the Lower Middle Horsepen WMA continues to develop. A slight decrease in estate residential, low intensity commercial and open space land use, with a corresponding increase in high density residential, high intensity commercial and institutional areas is projected within the Lower Middle Horsepen WMA.

4.5.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was completed within the Fairfax County portion of Lower Middle Horsepen WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Lower Middle Horsepen WMA:

1. Evaluated drainage complaints.
2. Documented new construction.
3. Evaluated projects proposed by the county.
4. Evaluated existing stormwater facilities.
5. Reviewed stream physical assessment inventory points.
6. Conducted neighborhood source assessments.
7. Conducted hot spot investigations.

The results of each of the above evaluations are briefly described in the following sections.

Drainage Complaints

Seventy seven (77) drainage complaints have been documented within the Lower Middle Horsepen WMA between 2001 and 2006. Of those, two representative complaints were chosen for field investigation. The complaints included erosion around a stormwater management facility and a stormwater infrastructure problem. Field reconnaissance indicated no erosion or infrastructure problems.

New Construction

To document areas of growth or re-growth within the watershed, new construction areas were identified for field reconnaissance. Two new single family residences were field verified, although no new construction was found.

Proposed County Projects

Based upon past evaluations and reports, multiple stormwater projects have been proposed within the Lower Middle Horsepen WMA. Field investigations were conducted to determine whether the projects were still viable. The projects included two culvert replacement projects under Rock Hill Road, the purchase of a flooded property and two stream restoration and stabilization projects.

Existing Stormwater Facilities

Four stormwater management facilities were evaluated within the Lower Middle Horsepen WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facility. One of the four facilities was found to not provide stormwater management functions. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Stream Physical Assessment (SPA) Inventory Points

Inventory points identified during the original stream physical assessment that received an impact score of five or greater were field verified. A cable utility line was identified within the streams banks. The broken utility line was still present, but was no longer functioning.

Neighborhood Source Assessment (NSA)

One representative neighborhood was chosen for a NSA to help identify potential improvement projects throughout the Lower Middle Horsepen WMA. The neighborhood consisted of single-family detached houses on lot sizes less than a quarter-acre. The neighborhood conditions, as well as the lack of stormwater management facilities, were evaluated. The NSA indicated the potential for stormwater management facilities and a need for better lawn and landscaping practices.

Hot Spot Investigation (HSI)

Four representative facilities with the potential to generate concentrated stormwater pollution were chosen within the Lower Middle Horsepen WMA for the HSI. An investigation was conducted of each facility and the corresponding property to identify sources of pollution. A convenience store, office building, school and department store were targeted for the HSI within the Lower Middle Horsepen WMA. One of the facilities was not identified a hot spot, two of the facilities were potential hot spots and one facility was a confirmed hot spot. This indicated the need for future education efforts, follow up on-site inspections, illicit discharge testing and the need for review of stormwater pollution prevention plans.

Stream Physical Assessment (SPA)

A supplemental stream physical assessment was conducted on 0.5 miles of stream within the Lower Middle Horsepen WMA. The stream was found to have fair to good habitat conditions. Multiple inventory points were identified with impact scores of five or higher including five erosion areas, two obstructions, three ditches and one utility line.

4.5.4 Lower Middle Horsepen WMA Characterization

Approximately one mile of stream was assessed within the Lower Middle Horsepen WMA to determine the overall stream conditions. As shown in Figure 4.4 the majority of the main stem has good to fair habitat conditions. All of the streams within the Fairfax County portion of Lower Middle Horsepen WMA are protected by the resource protection area, as described in Chapter 1. The stream was designated as protected in 2003. Several pipes, deficient riparian buffer areas, obstructions, stream crossings, and a utility were identified during field reconnaissance, although the majority of the problems were considered minor to moderate. One of the deficient riparian buffers was considered moderate to severe; however the restoration potential for this area was low. The surveyed channels in this WMA are in Channel Evolution Model Stage 3. This indicates an unstable channel that is experiencing significant bank erosion.

As shown in Figure 4.6, the Lower Middle Horsepen WMA contains a handful of stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network, including dry ponds, wet ponds and farm ponds. Table 4.17 provides treatment information for the portion of the Lower Middle Horsepen WMA located within Fairfax County.

Information regarding treatment within Loudoun County would be required to adequately calculate the total treatment coverage. Approximately 31 percent of the land in this WMA is impervious. More stormwater management is needed within the Lower Middle Sugarland WMA. Drainage complaints made by residents consisted of erosion and infrastructure problems.

Table 4.17 Lower Middle Horsepen WMA Summary

WMA Name	Total Area (acres)	Impervious Current Condition (acres)	Percent Impervious	Current Treatment Types*			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Lower Middle Horsepen	1,186	379.7	32%	1.5*	41.9*	71.9*	1,071

* Treatment only within Fairfax County

4.5.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen, and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.18 shows the total pollutant loading to the endpoint of Lower Middle Horsepen WMA. According to the STEPL model results, the Lower Middle Horsepen WMA contributes approximately 11 percent of the total suspended solids, 12 percent of the total nitrogen, and 13 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Lower Middle Horsepen WMA are presented in Table 3.19. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Lower Middle Horsepen WMA as compared with unit area loads for the entire watershed.

Table 4.18 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Lower Middle	329.0	10,617.54	1,669.08
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.19 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Lower Middle	0.277	8.937	1.405
WS Totals	**0.205**	**6.069**	**0.894**

4.5.6 HEC-RAS Modeling

The Lower Middle Horsepen WMA was not modeled in HEC-RAS because the contributing drainage area within Fairfax County was not considered substantial.

4.5.7 Lower Middle Horsepen Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. No potential problem areas were identified within the Lower Middle Horsepen WMA. Based upon existing conditions, the WMA is in a moderate condition.

The Lower Middle Horsepen WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. No additional subwatersheds within the Lower Middle WMA have been identified as additional problem areas. The Lower Middle Horsepen WMA was ranked as having low to moderate levels of stressors and pollutant sources.

4.6 Merrybrook WMA

4.6.1 Merrybrook WMA Characteristics

The Merrybrook WMA is located in the central portion of the Horsepen Creek Watershed and is bordered on the east by Sugarland Run Watershed. A small portion on the western side of the WMA lies within Loudoun County. The Merrybrook WMA is the third smallest WMA in the Horsepen Creek Watershed and consists of 967 acres (1.5 square miles). The WMA is bordered on the north by the Dulles Access Road and bordered on the west by Sully Road. See Figure 4.1 for the location of the Merrybrook WMA.

There are approximately two miles of perennial streams within the Merrybrook WMA. The streams flow in a western direction into Loudoun County before flowing into the main stem of Horsepen Creek. The streams flow through a combination of high density residential, low intensity commercial and open space areas. Two areas designated as parkland are located within the Merrybrook WMA, including Chandon Park.

4.6.2 Existing and Future Land Use

Approximately 77 percent of the Merrybrook WMA is urbanized, consisting primarily of medium and high density residential (24 percent), commercial (35 percent) and transportation networks (18 percent) land uses, as shown in Table 4.20. Approximately 15 percent of the area in this WMA is open space, which is primarily located around stream corridors.

Table 4.20 Existing and Future Land Use

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	4.8	0.7
High Density Residential	22.4	22.7
Medium Density Residential	1.7	1.7
Low Density Residential	0.4	1.9
High Intensity Commercial	0.9	11.7
Low Intensity Commercial	33.8	35.7
Industrial	0.7	1.3
Institutional	1.1	0.0
Open Space	14.9	5.0
Transportation	17.8	17.8
Water	1.4	1.4
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.20 and Figure 4.2 show the expected change in land use as the Merrybrook WMA continues to develop. A decrease in estate residential, institutional and open space land use, with a corresponding increase in high density residential, low density residential, high and low intensity commercial and industrial areas is projected within the Merrybrook WMA.

4.6.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was completed in the Fairfax County portion of Merrybrook WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Merrybrook WMA:

1. Evaluated drainage complaints.
2. Documented new construction.
3. Evaluated projects proposed by the county.
4. Evaluated existing stormwater facilities.
5. Conducted neighborhood source assessments.
6. Conducted hot spot investigations.

The results of each of the above evaluations are briefly described in the following sections.

Drainage Complaints

Ten (10) drainage complaints have been documented within the Merrybrook WMA between 2001 and 2004. Of those, one representative complaint was chosen for field investigation. The complaint included streambank erosion along Centreville Road. Field reconnaissance indicated the streambanks have already been stabilized with geotextile matting and vegetation in this area.

New Construction

To document areas of growth or re-growth within the watershed, new construction areas were identified for field reconnaissance. Six new construction areas were field verified including commercial buildings, a townhouse complex, and apartment buildings. All of the locations were either under construction or recently finished.

Proposed County Projects

Based upon past evaluations and reports, multiple stormwater projects have been proposed within the Merrybrook WMA. Field investigations were conducted to determine whether the projects were still viable. The projects included two stream restoration and stabilization projects. Field investigation also verified the completion of a regional pond and a culvert replacement project on Woodland Park Road.

Existing Stormwater Facilities

Six stormwater management facilities were evaluated within the Merrybrook WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facility. One of the six facilities was found to not provide stormwater management functions. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Neighborhood Source Assessment (NSA)

Two representative neighborhoods were chosen for a NSA to help identify potential improvement projects throughout the Merrybrook WMA. The neighborhoods consisted of a low intensity commercial area and multi-family housing. The neighborhood conditions, as well as the stormwater management facilities, were evaluated. The NSAs indicated the potential for stormwater management facility retrofit and a need for better lawn and landscaping practices.

Hot Spot Investigation (HSI)

Three representative facilities with the potential to generate concentrated stormwater pollution were chosen within the Merrybrook WMA for the HSI. An investigation was conducted of each facility and the corresponding property to identify sources of pollution. Three varying commercial establishments were targeted for the HSI within the Merrybrook WMA. All three of the facilities were identified as potential hot spots. This indicates the need for future education efforts and the need for review of stormwater pollution prevention plans.

Stream Physical Assessment (SPA)

A supplemental stream physical assessment was conducted on 0.5 miles of stream within the Merrybrook WMA. The section was chosen for reassessment because two county stream restoration and stabilization projects were located in the WMA. The stream was found to have fair to good habitat conditions. Only one inventory point was identified with an impact score of five or higher, an obstruction of trees and sediment.

4.6.4 Merrybrook WMA Characterization

Approximately 1.2 miles of stream was assessed within the Merrybrook WMA to determine the overall stream conditions in the WMA. As shown in Figure 4.4, the entire length of the Merrybrook Branch has good to fair habitat conditions. All of the streams in the WMA are

protected by the resource protection area, as described in Chapter 1. The stream was designated as protected in 1993. Several pipes, deficient riparian buffer areas, obstructions and stream crossings identified during field reconnaissance, although the problems were considered minor to moderate. The surveyed channels in this WMA are in Channel Evolution Model Stage 3. This indicates an unstable channel that is experiencing significant bank erosion.

As shown in Figure 4.6, the Merrybrook WMA contains multiple stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network, including dry ponds, wet ponds and farm ponds. A stormwater regional pond is actively being funded for construction. Table 4.21 indicates that stormwater runoff from approximately 19 percent of the area in this WMA is treated, and approximately 81 percent of the area in this WMA is not treated by any means. Stormwater runoff from the areas that do receive treatment are treated for both quantity and water quality. Approximately 41 percent of the area in this WMA is impervious. More stormwater management facilities are needed in the Upper Middle Sugarland WMA.

Table 4.21 Merrybrook WMA Summary

WMA Name	Total Area (acres)	Impervious Current Condition (acres)	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Merrybrook	967	396.2	41%	68.4	0	115.1	783.5

4.6.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.22 below shows the total pollutant loading to the endpoint of Merrybrook WMA. According to the STEPL model results, the Merrybrook WMA contributes approximately 7 percent of the total suspended solids, 10 percent of the total nitrogen, and 9 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Merrybrook WMA are presented in Table 4.23. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Merrybrook WMA as compared with unit area loads for the entire watershed.

Table 4.22 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Merrybrook	213.3	8,457.03	1,191.94
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.23 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Merrybrook	0.221	8.746	1.233
WS Totals	**0.205**	**6.069**	**0.894**

4.6.6 HEC-RAS Modeling

The Merrybrook WMA was not modeled in HEC-RAS because the contributing drainage area within Fairfax County was not considered substantial.

4.6.7 Merrybrook WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. No potential problem areas were identified within the Merrybrook WMA. Based upon existing conditions, the WMA is in fair condition.

The Merrybrook WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. No additional subwatersheds within the Merrybrook WMA have been identified as additional problem areas. The Merrybrook WMA was ranked as having moderate levels of stressors and pollutant sources

4.7 Middle Horsepen WMA

4.7.1 Middle Horsepen WMA Characteristics

The Middle Horsepen WMA is located in the central portion of the Horsepen Creek Watershed. A small portion of the northern tip lies within Loudoun County. The Middle Horsepen WMA is the second smallest in the Horsepen Creek Watershed and consists of 953 acres (1.5 square miles). The WMA is bordered on the east by Centreville Road and traversed by Sully Road. See Figure 4.1 for the location of the Middle Horsepen WMA.

There are approximately 2.9 miles of perennial streams within the Middle Horsepen WMA. The streams in the upper portion of the WMA are in good to fair condition, and streams in the lower portion of the WMA are in poor to very poor conditions. The streams flow in a northern direction into Loudoun County and flow through a combination of land uses. A portion of the open space along Horsepen Creek has been designated as parkland within the Middle Horsepen WMA.

4.7.2 Existing and Future Land Use

Approximately 60 percent of the Middle Horsepen WMA is urbanized, consisting primarily of medium and high density residential (7 percent), commercial and industrial (46 percent) and transportation networks (5 percent) land uses, as shown in Table 4.24. Open space makes up almost 28 percent of the land use in this WMA.

Table 4.24 Existing and Future Land Use

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	7.2	0.5
High Density Residential	5.9	6.9
Medium Density Residential	0.8	0.8
Low Density Residential	9.5	10.2
High Intensity Commercial	7.2	6.9
Low Intensity Commercial	8.6	9.2
Industrial	29.7	42.3
Institutional	1.7	1.7
Open Space	27.8	15.1
Transportation	5.1	5.1
Water	1.1	1.1
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.24 and Figure 4.2 show the expected change in land use as the Middle Horsepen WMA continues to develop. A decrease in estate residential, high intensity commercial and open space land use, with a corresponding increase in high density residential, low density residential, low intensity commercial and industrial areas is projected within the Middle Horsepen WMA.

4.7.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was completed within the Fairfax County portion of the Middle Horsepen WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Middle Horsepen WMA:

1. Evaluated drainage complaints.
2. Documented new construction.
3. Evaluated projects proposed by the county.
4. Evaluated existing stormwater facilities.
5. Reviewed stream physical assessment inventory points.
6. Reviewed on-site septic areas.
7. Conducted neighborhood source assessments.
8. Conducted hot spot investigations.

The results of each of the above evaluations are briefly described in the following sections.

Drainage Complaints

Eighteen (18) drainage complaints have been documented within the Middle Horsepen WMA during 2001. Of those, one representative complaint was chosen for field investigation. The complaint sited erosion around stormwater infrastructure. Field reconnaissance indicated minor erosion around a stormwater inlet that should be monitored.

New Construction

To document areas of growth or re-growth within the watershed, new construction areas were identified for field reconnaissance. A new office building was field verified, and the building was still under construction.

Proposed County Projects

Based upon past evaluations and reports, multiple stormwater facility projects have been proposed within the Middle Horsepen WMA. Field investigations were conducted to determine whether these projects were still viable. The projects included three stream restoration and stabilization projects of Horsepen Creek and the construction of regional pond. Field investigation also verified the completion of a culvert replacement project under Sully Rd, a culvert replacement project under Frying Pan Road and a culvert replacement project under McLearen Road.

Existing Stormwater Facilities

Nine stormwater management facilities were evaluated within the Middle Horsepen WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facilities. Three of the six facilities did not exist and one of the facilities could not be accessed. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Stream Physical Assessment (SPA) Inventory Points

Inventory points identified during the original stream physical assessment and which received an impact score of five or greater were field verified. Six sites were verified including three tree obstructions and three areas of erosion. Two of the areas of erosion were directly connected to stormwater management facilities.

On-site Septic

Portions of the Horsepen Creek watershed still use on-site septic systems. Properties using on-site systems were chosen for field reconnaissance if problems were noted in the area. One on-site septic area was visited along Frying Pan Road, although no problem was noted.

Neighborhood Source Assessment (NSA)

Three representative neighborhoods were chosen for a NSA to help identify potential improvement projects throughout the Middle Horsepen WMA. The neighborhoods consisted of two low-intensity commercial areas and a multi-family housing complex. The neighborhood conditions, as well as the stormwater management facilities, were evaluated. The NSAs indicated

the potential for stormwater management facility retrofit and a need for better lawn and landscaping practices.

Hot Spot Investigation (HSI)
Three representative facilities with the potential to generate concentrated stormwater pollution were chosen within the Middle Horsepen WMA to for the HSI. An investigation was conducted of each facility and the corresponding property to identify sources of pollution. Two schools and a retail area were targeted for the HSI within the Middle Horsepen WMA. All three of the facilities were identified as potential hot spots. This indicated the need for future education efforts and the need for review of the stormwater pollution prevention plan.

Stream Physical Assessment (SPA)
A supplemental stream physical assessment was conducted on 0.9 miles of stream within the Middle Horsepen WMA. The section was chosen for reassessment because three county stream restoration and stabilization projects and six SPA inventory points were identified within the WMA. The stream was found to have fair to good habitat conditions. Multiple inventory point was identified with an impact score of five or higher including two erosion problems, 13 obstructions and four ditches.

4.7.4 Middle Horsepen WMA Characterization

Approximately 2 miles of stream was assessed within the Middle Horsepen WMA to determine the overall stream conditions in the WMA. As shown in Figure 4.4, the upper portion of Horsepen Creek within the Middle Horsepen WMA has good to fair habitat conditions. The lower portion of Horsepen Creek within the Middle Horsepen WMA has poor to very poor conditions. All of the streams in the WMA are protected by the resource protection area, as described in Chapter 1. The main steam was designated as protected in 1993 and one of the tributaries was added in 2003 and 2005. A pipe, several deficient riparian buffer areas, obstructions, ditches, headcuts, stream crossings and an area of erosion were identified during field reconnaissance. Most of the problems that were identified were considered minor to moderate. Several of the deficient buffer areas were considered moderate to severe; however, their restoration potential was also consider low. One ditch, four headcuts and one stream crossing were ranked moderate to severe. Several obstructions were ranked moderate to severe, and two obstructions ranked severe to extreme. The surveyed channel within the Middle Horsepen WMA is in Channel Evolution Model (CEM) Stage 3. This indicates an unstable channel that is experiencing significant bank erosion. All of the SPA inventory points indicate that Horsepen Creek is unstable throughout the Middle Sugarland WMA.

As shown in Figure 4.6, the Middle Horsepen WMA contains multiple stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network, including dry ponds, wet ponds and farm ponds. A stormwater regional pond is actively being funded for construction at the end of Cedar Run Lane. Table 4.25 indicates that stormwater runoff from approximately 14 percent of the area in this WMA is treated, and approximately 86 percent of the area in this WMA is not treated by any means. Stormwater runoff from the areas that do receive treatment are mainly treated for quantity and not water quality. Approximately 23 percent of the area in this WMA is impervious. More stormwater management facilities are

needed in the Upper Middle Sugarland WMA. Drainage complaints made by residents consisted of erosion around stormwater infrastructure.

Table 4.25 Middle Horsepen WMA Summary

WMA Name	Total Area (acres)	Impervious Current Condition (acres)	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/ Quality (acres)	None (acres)
Middle Horsepen	953	215.1	23%	102.2	18.7	9.2	822.9

4.7.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.26 below shows the total pollutant loading to the endpoint of Middle Horsepen WMA. According to the STEPL model results, the Middle Horsepen WMA contributes approximately 6 percent of the total suspended solids, 6 percent of the total nitrogen, and 6 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Middle Horsepen WMA are presented in Table 4.27. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Middle Horsepen WMA as compared with unit area loads for the entire watershed.

Table 4.26 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Middle Horsepen	180.1	5,679.34	739.50
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.27 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Middle Horsepen	0.189	5.959	0.776
WS Totals	**0.205**	**6.069**	**0.894**

4.7.6 HEC-RAS Modeling

HEC-RAS hydraulic modeling was completed for a 100-year storm event in the Middle Horsepen WMA. Channel flow capacity was analyzed to determine if the 100-year storm event would overflow the channel and flood onto the floodplain. Additionally, the elevation of the flow was determined with reference to the topographic elevations in the stream valley.

As shown in Figure 4.11, a 100-year storm in the Middle Horsepen WMA resulted in an overflow event with flooding onto the floodplain. The modeling showed that the 100-year stormflow elevation covered the entire floodplain and reached up the valley slope.

One bridge and two culverts are located within the Middle Horsepen WMA. This bridge and culverts were modeled to determine if the 100-year storm exceeded their capacity to carry the flow. The modeling shows that the bridge does not carry the 100-year stormflow and the water may possibly overtop the bridge structure. One culvert cannot carry the 100-year stormflow and will overtop. The second culvert will carry the 100-year stormflow.

4.7.7 Middle Horsepen WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. Two subwatersheds within the Middle Horsepen WMA have been identified as a potential problem area. Based upon existing conditions, the Middle Horsepen WMA is in poor to very poor conditions condition.

The Middle Horsepen WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. No additional subwatersheds within the Middle Horsepen WMA have been identified as additional problem areas. The southern portion of the WMA was ranked as having moderate levels of stressors and pollutant sources. The northern portion of the WMA was ranked as having low to moderate levels of stressors and pollutant sources.

4.8 Stallion WMA

4.8.1 Stallion WMA Characteristics

The Stallion WMA is located in the western portion of the Horsepen Creek Watershed. The WMA lies entirely within Loudoun County. The Stallion WMA is the second largest in the Horsepen Creek Watershed and is comprised of 2,394 acres (3.7 square miles). See Figure 4.1 (WMA Map) for the location of the Stallion WMA.

There are approximately 3.2 miles of perennial streams within the Stallion WMA. The streams flow in a northern direction into the Lower Horsepen WMA. The streams flow primarily through open space areas.

4.8.2 Existing and Future Land Use

Approximately 16 percent the Stallion WMA is urbanized, consisting primarily of residential (2 percent) and industrial (14 percent) land uses, as shown in Table 4.28. The industrial area is comprised of the Dulles International Airport which covers a portion of the WMA. The land use in over 80 percent of this WMA is open space.

Table 4.28 Existing and Future Land Use

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	0.0	0.0
High Density Residential	0.1	0.1
Medium Density Residential	0.4	0.4
Low Density Residential	1.5	1.5
High Intensity Commercial	0.0	0.0
Low Intensity Commercial	0.0	0.0
Industrial	14.2	14.2
Institutional	0.0	0.0
Open Space	81.3	81.3
Transportation	0.0	0.0
Water	2.5	2.5
Total	100	100

Source: Fairfax County GIS, 2008

Table 4.28 and Figure 4.3 indicate no change in land use within the Stallion WMA is expected.

4.8.3 Field Reconnaissance and Stream Physical Assessment

No field reconnaissance was completed for the Stallion WMA since it is located completely in Loudoun County.

4.8.4 Stallion WMA Characterization

No stream condition information is available or has been collected for the Stallion WMA since it is located completely in Loudoun County.

The current stormwater treatment types for the Stallion WMA are unknown and unmapped, as all of this WMA is located in Loudoun County. Approximately 8 percent of this WMA is impervious, and no information is known about the stormwater treatment facilities in this WMA.

4.8.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10 present the results of the STEPL model for total suspended solids, total nitrogen and total phosphorus, respectively, which were used to estimate the pollutant loadings

in each subwatershed and WMA. Table 4.29 shows the total pollutant loading to the endpoint of Stallion WMA. According to the STEPL model results, the Stallion WMA contributes approximately 13 percent of the total suspended solids, 8 percent of the total nitrogen, and 8 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Stallion WMA are presented in Table 4.30. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Stallion WMA as compared with unit area loads for the entire watershed.

Table 4.29 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Stallion	378.6	6,796.83	1,052.83
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.30 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Stallion	0.158	2.839	0.440
WS Totals	**0.205**	**6.069**	**0.894**

4.8.6 HEC-RAS Modeling

Because the Stallion WMA is located completely in Loudoun County, HEC-RAS modeling was not completed.

4.8.7 Stallion WMA Subwatershed Ranking

No subwatershed ranking was completed for the Stallion WMA since it is located completely in Loudoun County.

4.9 Upper Horsepen WMA

4.9.1 Upper Horsepen WMA Characteristics

The Upper Horsepen WMA is located in the southern tip of the Horsepen Creek Watershed. The Upper Horsepen WMA is the fourth largest in the Horsepen Creek Watershed and it is comprised of 1,929 acres (3 square miles). The WMA is bordered on the east by the Reston Parkway, Lawyers Road and West Ox Road, and it is bordered on the west by Centreville Road. See Figure 4.1 for the location of the Upper Horsepen WMA.

There are approximately 7.3 miles of perennial streams within the Upper Horsepen WMA. The majority of streams are in good to fair condition, although there are some small portions in poor to very poor condition. The streams flow in a northwest direction into the Middle Horsepen WMA. The stream travels through primarily medium density residential and open space areas. A portion of the open space along Horsepen Creek has been designated as parkland within the Upper Horsepen WMA.

4.9.2 Existing and Future Land Use

Approximately 76 percent of the Upper Horsepen WMA is urbanized, consisting primarily of high and medium density residential (52 percent), commercial and industrial (4 percent), institutional (3 percent) and transportation networks (17 percent) land uses, as shown in Table 4.31. The open space land use is primarily located around the stream corridors.

Table 4.31 and Figure 4.2 show the expected change in land use as the Upper Horsepen WMA continues to develop. A decrease in estate residential, low intensity commercial and open space land uses, with a corresponding increase in medium and low density residential, high intensity commercial and industrial areas is projected within the Upper Horsepen WMA.

Table 4.31 Existing and Future Land Use for Upper Horsepen WMA

Land Use Type	Existing	Future
	Percent (%)	Percent (%)
Estate Residential	1.0	0.3
High Density Residential	2.2	2.2
Medium Density Residential	50.2	50.9
Low Density Residential	3.7	4.2
High Intensity Commercial	2.2	2.5
Low Intensity Commercial	1.6	1.4
Industrial	0.4	0.8
Institutional	3.0	3.0
Open Space	18.1	17.1
Transportation	16.9	16.9
Water	0.9	0.9
Total	100	100

Source: Fairfax County GIS, 2008

4.9.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was completed within the Upper Horsepen WMA to evaluate projects proposed by the county, to identify problems areas and to identify potential improvement projects. The following tasks were completed during the field reconnaissance surveys of the Upper Horsepen WMA:

1. Evaluated drainage complaints.
2. Documented new construction.
3. Evaluated projects proposed by the county.
4. Evaluated existing stormwater facilities.
5. Reviewed stream physical assessment inventory points.
6. Reviewed on-site septic areas.
7. Conducted neighborhood source assessments.
8. Conducted hot spot investigations.

The results of each of the above evaluations are briefly described in the following sections.

Drainage Complaints

Two hundred and fifty nine (259) drainage complaints have been documented within the Upper Horsepen WMA between 2001 and 2006. Of those, 26 representative complaints were chosen for field investigation. The complaints sited erosion around stormwater infrastructure and management facilities, odor from stormwater infrastructure and streambank erosion. Field reconnaissance indicated minor erosion around several stormwater inlets, no foul odors and some minor streambank erosion.

New Construction

To document areas of growth or re-growth within the watershed, new construction areas were identified for field reconnaissance. A new office building was field verified and the building was still under construction.

Proposed County Projects

Based upon past evaluations and reports, multiple stormwater projects have been proposed within the Upper Horsepen WMA. Field investigations were conducted to determine whether these projects were still viable. The projects included two stream restoration and stabilization projects on Horsepen Creek, a culvert replacement project under Viking Drive, a regional pond near the Fairfax County Parkway and a culvert replacement project under West Ox Road. Field investigation also verified the completion of a culvert replacement project under Centreville Road and a regional pond constructed near West Ox Road.

Existing Stormwater Facilities

Eighteen (18) stormwater management facilities were evaluated within the Upper Horsepen WMA to determine the need for repair or the potential for retrofit to increase the benefit of the facility. Four of the 18 facilities were not providing stormwater management. The remaining facilities were functioning as designed, although most presented some opportunity for retrofit.

Stream Physical Assessment (SPA) Inventory Points

Inventory points identified during the original stream physical assessment and which received an impact score of five or greater were field verified. Fourteen (14) sites were verified including a stream crossing, two tree obstructions, a utility, seven areas of erosion, and two pipes. Two of the inventory points, an area of erosion and a pipe, were unable to be found, and therefore were not verified.

On-site Septic

Portions of the Horsepen Creek watershed still use on-site septic systems. Properties using on-site systems were chosen for field reconnaissance if problems were noted in the area. Three on-site septic areas were field verified, but no problems were noted. One of the sites was being re-developed and it is expected that it will not longer use an on-site septic system.

Neighborhood Source Assessment (NSA)

Five representative neighborhoods were chosen for a NSA to help identify potential improvement projects throughout the Upper Horsepen WMA. The neighborhoods consisted of a low intensity commercial area and four single family developments. The single- family detached housing was located on one-quarter to half-acre lots. The neighborhood conditions, as well as the stormwater management facilities, were evaluated. The NSAs indicated the potential for stormwater management facility retrofit and a need for better lawn and landscaping practices.

Hot Spot Investigation (HSI)

Four representative facilities with the potential to generate concentrated stormwater pollution were chosen within the Upper Horsepen WMA for the HSI. An investigation was conducted of each facility and the corresponding property to identify sources of pollution. Two schools and a convenience store/gas station were targeted for the HSI within the Upper Horsepen WMA. A dry cleaning establishment was also targeted, but it was no longer in business. All three of the facilities were identified as potential hot spots. This indicated the need for future education efforts and the need for review of the stormwater pollution prevention plan.

Stream Physical Assessment (SPA)

A supplemental stream physical assessment was conducted on 1.1 miles of stream within the Upper Sugarland WMA. The section was chosen for reassessment because two county stream restoration and stabilization projects, 10 SPA inventory points, and an erosion drainage complaint were identified within the WMA. The stream was found to have fair to good habitat conditions. Multiple inventory point was identified with an impact score of five or higher including 20 erosion problems and three obstructions.

4.9.4 Upper Horsepen WMA Characterization

Approximately seven miles of stream was assessed within the Upper Horsepen WMA to determine the overall stream conditions. As can be seen from Figure 4.4, the main stem of Horsepen Creek within the Upper Horsepen WMA has good to fair habitat conditions. A few of the tributaries have poor to very poor conditions. All of the streams in the WMA are protected by the resource protection area, as described in Chapter 1. The main steam was designated as protected in 1993, whereas the tributaries and headwaters were added in 2003 and 2005. Pipes, deficient riparian buffer areas, obstructions, ditches, headcuts, utilities, dumps, stream crossings and areas of erosion were identified during field reconnaissance, although most of the problems were considered minor to moderate. Some of the points were ranked severe to extreme including a headcut of 2.5 feet, a tree obstruction on a tributary and a pipe causing major erosion. Based on the stream length that was surveyed within the Upper Horsepen WMA, the entire channel is in Channel Evolution Model Stage 3. This indicates an unstable channel that is experiencing

significant bank erosion. All of the SPA inventory points support the instability rating of Horsepen Creek through the Upper Horsepen WMA.

As shown in Figure 4.6, the Upper Horsepen WMA contains multiple stormwater management facilities that collect and treat stormwater runoff before it reaches the stream network, including dry ponds, wet ponds and farm ponds. A stormwater regional pond has been constructed near West Ox Road and one is planned for construction near the Fairfax County Parkway. Based on Table 4.25, stormwater runoff from approximately 32 percent of the area in this WMA is treated, and stormwater runoff from approximately 68 percent of the area in this WMA is not treated by any means. Stormwater runoff from the areas that do receive treatment is treated for both quantity and water quality. Approximately 29 percent of the area in this WMA is impervious. More stormwater management facilities are needed in the Upper Middle Sugarland WMA. Drainage complaints made by residents consisted of erosion around stormwater infrastructure and facilities, streambank erosion, and foul odors.

Table 4.32 Upper Horsepen WMA Summary

WMA Name	Total Area (acres)	Impervious Current Condition (acres)	Percent Impervious	Current Treatment Types			
				Quantity (acres)	Quality (acres)	Quantity/Quality (acres)	None (acres)
Upper Horsepen	1,929	556.4	29%	373.3	56.9	188.4	1,310.4

4.9.5 STEPL Modeling

Figures 4.8, 4.9 and 4.10. present the results of the STEPL model for total suspended solids, total nitrogen and total phosphorus, respectively, which were used to estimate the pollutant loadings in each subwatershed and WMA. Table 4.33 shows the total pollutant loading to the endpoint of Upper Horsepen WMA. According to the STEPL model results, the Upper Horsepen WMA contributes approximately 12 percent of the total suspended solids, 17 percent of the total nitrogen, and 18 percent of the total phosphorous annual loads to the Horsepen Watershed. Pollutant loadings normalized to the acres within the drainage area of Upper Horsepen WMA are presented in Table 3.33. The values in this table indicate the total nutrient and sediment load that results from stormwater runoff over one acre of Upper Horsepen WMA as compared with unit area loads for the entire watershed.

Table 4.33 Summary of Pollutant Loadings

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/year)	Total Nitrogen (pounds/year)	Total Phosphorus (pounds/year)
Upper Horsepen	364.7	15,343.90	2,289.32
WS Totals	**2,992.98**	**88,606.20**	**13,047.25**

Table 4.34 Summary of Pollutant Loadings Normalized by Drainage Area

WMA Name	Pollutant Loadings		
	Total Suspended Solids (tons/acre/year)	Total Nitrogen (pounds/acre/year)	Total Phosphorus (pounds/acre/year)
Upper Horsepen	0.189	7.954	1.187
WS Totals	**0.205**	**6.069**	**0.894**

4.9.6 HEC-RAS Modeling

HEC-RAS hydraulic modeling was completed for a 100-year storm event in the Upper Horsepen WMA. Channel flow capacity was analyzed to determine if the 100-year storm event would overflow the channel and flood onto the floodplain. Additionally, the elevation of the flow was determined with reference to the topographic elevations in the stream valley.

As shown in Figure 4.11, a 100-year storm in the Upper Horsepen WMA resulted in an overflow event with flooding onto the floodplain. The modeling showed that the 100-year stormflow elevation covered the entire floodplain and reached up the valley slope.

Three culverts and a paired weir and culvert are located within the Upper Horsepen WMA. The culverts and the paired weir and culvert were modeled to determine if the 100-year storm exceeded their capacity to carry the flow. The modeling shows that three culverts carry the 100-year stormflow. The modeling for the paired weir and culvert shows that the weir is overtopped and the culvert outlet does not carry the 100-year stormflow.

4.9.7 Upper Horsepen WMA Subwatershed Ranking

As indicated in Section 2.6, two indicator categories – watershed impact and source indicators - were used for ranking overall stream conditions in the subwatersheds. Figure 4.12 illustrates the results obtained for subwatershed ranking of the watershed impacts. The lowest scoring subwatersheds were identified as potential problem areas. Two subwatersheds within the Upper Horsepen WMA have been identified as potential problem areas. The existing conditions within the WMA have been ranked as moderate.

The Upper Horsepen WMA was also evaluated using source indicators to identify potential WMA stressors or pollutant sources as shown in Figure 4.13. The lowest ranking subwatersheds were identified as additional potential problem areas. Two additional subwatersheds within the Upper Horsepen WMA have been identified as additional problem areas. The remainder of the Upper Horsepen WMA was ranked as having moderate to high levels of stressors and pollutant sources.

4.10 SWMM Modeling for Horsepen Creek Watershed

The Stormwater Management Model (SWMM) was used to determine the peak rate (maximum volume of water per second) of stormwater flows in stream channels during a storm. The 2-year and 10-year storm flows were modeled; these are the storm flows that, on average, occur once every 2 or 10 years. Figure 4.14 shows peak rates of flow for the 2-year storm across the watershed. As shown in Figure 4.14, within each WMA, peak flows tend to increase downstream as more drainage area contributes more stormwater runoff to the stream channel. In a similar manner, an upstream, contributing WMA augments the flow in a downstream, receiving WMA. Because stormwater runoff flow carries pollutants, pollutant loadings also increase downstream within a WMA and from one WMA to the next.

Table 4.35 shows peak flows for the 2-year and 10-year storms in the WMAs in the Horsepen Creek watershed. The SWMM model shows that peak flows are increasing from the upstream, contributing WMAs to the downstream WMAs. The Lower Horsepen WMA has the highest cumulative peak flows because it is the receiving WMA for all the stormwater runoff in the watershed. Peak flows for the 10-year storm are approximately twice as large as the flows for the 2-year storm.

Table 4.35 Summary of SWMM and STEPL Results

		Stormwater Runoff Peak Flow Values		Pollutant Loadings		
WMA Name[1]	**Contributing WMA(s) [2]**	**2-yr storm (cubic ft/sec)**	**10-yr storm (cubic ft/sec)**	**Total Suspended Solids (tons/yr)**	**Total Nitrogen (pounds/yr)**	**Total Phosphorus (pounds/yr)**
HC-Upper	Cedar, Upper	822.01	1622.37	526.69	21,314.45	3,197.37
HC-Middle	Upper, Frying Pan, Merrybrook, Middle	1587.46	3147.43	1,128.62	43,935.13	6,375.56
HC-Lower Middle	Middle, Lower Middle	1827.85	3764.58	1,457.57	54,552.68	8,044.65
HC-Lower	Lower Middle, Stallion, Indian, Lower	2456.98	5521.38	2,992.98	88,606.20	13,047.25
WS Totals		**2456.98**	**5521.38**	**2,992.98**	**88,606.20**	**13,047.25**

1. The "WMA Name" is the WMA for which there is a modeled cumulative peak flow (2 and 10 year) for the entire upstream drainage area.
2. The "Contributing WMA(s)" are the upstream WMAs for which there is nomodeled cumulative peak flows (2 and 10 year) for the entire upstream drainage area. Example: The "Upper" WMA includes all the stormwater draining from the Cedar WMA and the Upper WMA.

Figure 4.14 SWMM Peak Flow Map for Horsepen Creek Watershed

To determine which WMA contributes the greatest flows, the peak flows in Table 4.35 were recalculated based on WMA drainage area. Table 4.36 shows these flows normalized by WMA drainage area. Upper Horsepen WMA contributes the most stormwater runoff during the 2-year storm and Lower Horsepen WMA contributes the least. During the 10-year storm, the Upper Horsepen WMA contributes the most cumulative stormwater runoff per drainage area and the Lower Horsepen WMA the least.

The STEPL model was used to estimate the pollutant loadings for total suspended solids (sediments), total nitrogen, and total phosphorus for each WMA and the results are shown in Table 4.35. As stormwater flows accumulate downstream, so do the pollutant loadings carried by the flows. For instance, Table 4.35 shows the Upper, Frying Pan, Merrybrook and Middle WMAs contributing flows and pollutants to the Middle WMA. Pollutant loads increase from the upstream, contributing WMAs to downstream WMAs. The Lower Horsepen WMA contributes the greatest cumulative pollutant loading and the Upper WMA the least.

To determine if the pollutant loadings shown in Table 4.35 are increasing or decreasing with downstream flow, the pollutant loadings in Table 4.35 were recalculated based on WMA drainage area. Table 4.36 shows pollutant loadings normalized by the contributing drainage area. Pollutant loadings in the Horsepen Watershed decrease with downstream flow, indicating that the increase in flow is relatively greater than the increase in added pollutants.

Table 4.36 Summary of SWMM and STEPL Results Normalized by Drainage Area

			Stormwater Runoff Peak Flow Values		Pollutant Loadings		
WMA Name[1]	**Contributing WMA(s) [2]**	**Drainage Area (acres)**	**2-yr storm (cubic ft/sec)**	**10-yr storm (cubic ft/sec)**	**Total Suspended Solids (tons/yr)**	**Total Nitrogen (pounds/yr)**	**Total Phosphorus (pounds/yr)**
HC-Upper	Cedar, Upper	2,712	0.303	0.598	0.194	7.859	1.179
HC-Middle	Upper, Frying Pan, Merrybrook, Middle	5,763	0.275	0.546	0.196	7.624	1.106
HC-Lower Middle	Middle, Lower Middle	6,951	0.263	0.542	0.210	7.848	1.157
HC-Lower	Lower Middle, Stallion, Indian, Lower	14,600	0.168	0.378	0.205	6.069	0.894
WS Totals		14,600	**0.168**	**0.378**	**0.205**	**6.069**	**0.894**

3. The "WMA Name" is the WMA for which there is a modeled cumulative peak flow (2 and 10 year) for the entire upstream drainage area.
4. The "Contributing WMA(s)" are the upstream WMAs for which there is nomodeled cumulative peak flows (2 and 10 year) for the entire upstream drainage area. Example: The "Upper" WMA includes all the stormwater draining from the Cedar WMA and the Upper WMA.

5.0 Glossary of Terms

Acre – A measure of land equating to 43,560 square feet.

Aquatic Habitat – The wetlands, streams, lakes, ponds, estuaries, and streamside (riparian) environments where aquatic organisms (e.g., fish, benthic macroinvertebrates) live and reproduce; includes the water, soils, vegetation, and other physical substrate (rocks, sediment) upon and within which the organisms occur.

Benthic Macroinvertebrate – An aquatic animal lacking a backbone and generally visible to the unaided eye.

Best Management Practice (BMP) – A structural or nonstructural practice that is designed to minimize the impacts of changes in land use on surface and groundwater systems. Structural best management practices refer to basins or facilities engineered for the purpose of reducing the pollutant load in stormwater runoff, such as bioretention, constructed stormwater wetlands, etc. Nonstructural best management practices refer to land use or development practices that are determined to be effective in minimizing the impact on receiving stream systems such as the preservation of open space and stream buffers, disconnection of impervious surfaces, etc.

Bioengineering – Combines biological (live plants) and engineering (structural) methods to provide a streambank stabilization method that performs natural stream functions without habitat destruction.

Channel Evolution Model (CEM) – The geomorphologic assessment of the incised stream channels developed by Schumm et. al.

Channel – A natural or manmade waterway.

Confluence – The joining point where two or more stream create a combined, larger stream.

Design Storm – A selected rainfall hyetograph of specified amount, intensity, duration, and frequency that is used as a basin for design.

Detention – The temporary impoundment or holding of stormwater runoff.

Ecosystem – All the component organisms of a community and their environment that together form an interacting system.

Erosion - is the natural process by which a stream channel adjusts to changes within its watershed. Increased development within a watershed can accelerate the erosion process, resulting in the loss of residential yards, threatened infrastructure, siltation of aquatic habitat, and decreased water quality.

Floodplain - Area of land on each side of a stream channel that is inundated periodically by flood waters; important zone for dissipating the energy of peak storm flow discharges and for storing waters that otherwise might damage in-stream habitat and/or cause downstream flood damage; typically includes high-quality riparian habitat (if undisturbed); waters flowing in incised (down-cut) streams may not be able to access the adjacent floodplain area to dissipate the volume and energy of higher storm flow events.

Geographic Information System (GIS) – A method of overlaying spatial land and land use data of different kinds. The data are referenced to a set of geographical coordinates and encoded in a computer software system. GIS is used by many localities to map utilities and sewer lines and to delineate zoning areas.

Geomorphology – A science that deals with the land and submarine relief features of the earth's surface.

Headcut – The geomorphologic incision of the stream due to the hydraulic effect of a channel from head forces. One example is the accelerated cutting of a stream due to a manmade or natural constriction where water velocities are increased substantially. Another example is the outlet of a dam, where extreme velocities can occur due to the high static head forces created by the build-up of water from the dam structure.

Headwater – The source of a stream or watershed.

Hot Spot – A problem area that may contain significant stressors or pollutant sources that can affect watershed conditions within the immediate subwatershed and may be having an impact on downstream areas.

Hydraulics – The physical science and technology of the static and dynamic behavior of fluids.

Hydrograph – A plot showing the rate of discharge, depth, or velocity of flow versus time for a given point on a stream or drainage system.

Hydrology – The science of dealing with the distribution and movement of water.

Hyetograph – A graph of time distribution of rainfall over a watershed.

Impervious Surface – A surface composed of any material that significantly impedes or prevents natural infiltration of water into the soil. Impervious surfaces include, but are not limited to, roofs, buildings, streets, parking areas, any concrete, asphalt, or compacted gravel surface.

Modeling - Use of conceptual and/or computer models to simulate the response (e.g., pollutant loading to streams) of a natural system (e.g., watershed) to various management scenarios; useful in assessing which types of watershed protection techniques will yield the greatest benefit to water quality, habitat, or flooding conditions, and in determining which locations within the watershed are optimal for such practices or project sites.

Open Space – The area within the boundaries of a lot that is intended to provide light and air, and is designed for either scenic or recreational purposes. Open space shall, in general, be available for entry and use by residents or occupants of the development. Open space may include, but is not limited to, lawns, decorative planting, walkways, recreation areas, playgrounds, undisturbed natural areas and wooded areas.

Peak Discharge – The maximum rate of flow at an associated point within a given rainfall event or channel condition.

Perennial Stream – A body of water that normally flows year-round in a defined channel or bed, and is capable, in the absence of pollution or other manmade stream disturbances, of supporting bottom-dwelling aquatic animals.

Pipes - carry water from various sources to a stream. Because of this, the discharge may contain pollutants such as oil from roadway runoff, sewage, nutrients from lawn fertilization, etc. The high volume and flow delivered to the stream, particularly during storm events, can result in erosion of the stream channel and banks.

Redevelopment – The substantial alteration, rehabilitation, or rebuilding of a property for residential, commercial, industrial, or other purposes.

Resource Protection Area (RPA) – Vegetated riparian buffer areas, which include land within a major floodplain and land within 100 feet of a water body. These buffer areas are important in the reduction of sediments, nutrients, as well as the other adverse effects of human activities, which could potentially degrade these systems and those downstream.

Restoration - The re-establishment of wetlands or stream hydrology and wetlands vegetation into an area where wetland conditions (or stable streambank and stream channel conditions) have been lost.

Retention – The permanent storage of stormwater.

Retrofit – The modification of stormwater management systems through the construction and/or enhancement of wet ponds, wetland plantings, or other best management practices designed to improve water quality.

Return Period – The average length of time between events having the same volume and duration. If a storm has a one percent chance of occurring in any given year, then it has a return period of 100 years.

Riparian Buffer - An area adjacent to a stream, wetland, or shoreline where development activities (e.g., buildings, logging) are typically restricted or prohibited; may be managed as streamside (riparian) zones where undisturbed vegetation and soils act as filters of pollutants in stormwater runoff; buffer zone widths vary depending on state and local rules, but are typically a minimum of 25 to 50 feet on each side of perennial streams.

Road Crossing - are structures that span the width of a stream, usually road or foot bridges. The structures constrict the flow within a stream which can result in detrimental effects including erosion, flooding, and decreased water quality. In addition, structures may block fish and wildlife passage preventing migration to feeding/spawning areas.

Runoff – The portion of precipitation, snow melt, or irrigation water that runs off the land into surface waters.

Stormwater - Precipitation that is often routed into drain systems in order to prevent flooding.

Stormwater Management Facility – A device that controls stormwater runoff and changes the characteristics of that runoff including, but not limited to, the quantity and quality, the period of release or the velocity of flow.

Stream Restoration – The reestablishment of the general structure, function, and dynamic, but self-sustaining, behavior of the ecosystem.

Subwatershed – A subdivision of a watershed used for planning and management purposes, usually ranges in size from 100 to 300 acres.

Tree Cover – The area directly beneath the crown and within the dripline of a tree.

Watercourse – A stream with incised channel (bed and banks) over which water are conveyed.

Watershed – A defined land area drained by a river, stream, or drainage way, or system of connecting rivers, streams, or drainage ways such that all surface water within the area flows through a single outlet.

Watershed Management Area (WMA) – A subdivision of a watershed used for planning and management purposes, usually four square miles in size.

Watershed Planning - The development of basin wide Watershed Restoration Plans; planning typically includes (1) an assessment of watershed conditions and functional impacts at progressively smaller scales of study, and (2) the development of land use management strategies and optimal watershed restoration, enhancement and protection/preservation projects designed to address the identified watershed needs & opportunities.

Wetland - Habitats where the influence of surface water or groundwater has resulted in the development of plant or animal communities adapted to aquatic or intermittently wet conditions. Wetlands include tidal flats, shallow sub-tidal areas, swamps, marshes, wet meadows, bogs, and similar areas.