6.0 Benefits of Plan Implementation

There are numerous watershed restoration strategies that may have a significant impact on the overall health and quality of the Sugarland Run and Horsepen Creek watersheds. In order to quantify the costs and benefits of implementing the watershed restoration strategies discussed in previous sections, additional analyses were required. This section discusses and summarizes the results of the pollutant load, hydrologic and hydraulic modeling used in the development of the watershed management plans to quantify any reductions in pollutant loading, total stormwater runoff volumes, peak rate of runoff and the extent of flooding. A summary of cost estimates and an analysis of the costs and benefits of the project plan are also discussed.

6.1 Stormwater Models

As discussed in Section 2, modeling is a way to mathematically predict and spatially represent what will occur during a given rainfall event. Hydrologic and hydraulic models are the two types of models that are used to achieve this. *Hydrologic models* take into account the particular rainfall event of interest, the physical nature of the land area where the rainfall occurs and how quickly the resulting stormwater runoff drains a given land area. Hydrologic models can describe both the quantity of stormwater runoff and resulting pollution, such as nutrients (nitrogen and phosphorus) and sediment that are transported by the runoff. *Hydraulic models* are used to evaluate the effect the stormwater runoff from a particular rainfall event has on both man-made and natural systems. These models can predict both the ability man-made culverts/channels have in conveying stormwater runoff and the spatial extent of potential flooding.

Hydrologic and hydraulic models were created for three distinct scenarios as listed below:

- Existing conditions
- Future conditions without projects
- Future conditions with projects

For *Existing Conditions*, the models simulated the condition of the watersheds at the time the models were created by incorporating information on land use, soils, existing stormwater management and best management practice facilities, previous stream and watershed assessments and actual field reconnaissance and site visits. The *Future Conditions without Projects* scenario simulated future conditions based on countywide future land use and development, derived from the county's comprehensive plan and build-out predictions. As the name implies, the *Future Conditions without Projects* models do not contain any of the watershed restoration strategies or projects identified in this plan. The *Future Conditions with Projects* scenario simulates the implementation of the projects discussed in the previous sections. The *Future Conditions with Projects* scenario uses the *Future Conditions without Projects* models as a base on which proposed restoration strategies are added and evaluated. Comparison of modeling results from these three scenarios yielded pollutant loading and stormwater runoff reductions discussed below. Detailed information on the setup and calibration of the STEPL pollution models, SWMM hydrologic models and HEC-RAS hydraulic models can be found in Technical Memo 3.6 in Appendix B.

6.2 Analysis of Stormwater Modeling Results

Results of the modeling efforts were compiled and analyzed to determine pollutant load and flow reductions. The reduction in values shown and discussed below indicates the overall benefits of implementing the restoration strategies described within the plan.

6.2.1 Sugarland Run

Tables 6.1 and 6.2 below summarize the results of the pollutant and hydrologic models in terms of pollutant loading and stormwater flow reductions for the Sugarland Run Watershed. All values were normalized to the drainage area to allow for direct and accurate comparisons. Runoff volume and peak flow values were obtained from SWMM hydrologic models and were calculated cumulatively. In other words, flows were summed from upstream to downstream and were divided by the total contributing drainage area. Total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) values were obtained from the results of the STEPL pollutant models. These values were calculated based on the individual land area contributions and may not increase from upstream to downstream.

Table 6.1
Sugarland Run Pollutant Loading and Flow Reductions by WMA

WMA	Area (ac)	Scenario[3]	Runoff Volume (in/yr)[1]		Peak Flow (cfs/ac)[1]		TSS (lb/ac/yr)[2]	TN (lb/ac/yr)[2]	TP (lb/ac/yr)[2]
			2 Year	10 Year	2 Year	10 Year			
Folly Lick WMA	1,814	Existing Condition	2,086.37	4,742.46	0.240	0.546	259.16	6.068	0.927
		Future Without Projects	3,707.16	7,567.42	0.426	0.870	263.22	6.198	0.943
		Future With 10-yr Projects	3,674.52	7,510.86	0.423	0.864	258.29	6.116	0.930
		Reduction (10-year Plan)	-1%	-1%	-1%	-1%	-2%	-1%	-1%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	250.32	6.03	0.91
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-5%	-3%	-3%
Headwaters WMA	1,391	Existing Condition	3,772.97	7,239.01	0.434	0.833	258.99	7.239	0.974
		Future Without Projects	3,756.78	7,209.14	0.432	0.829	259.32	7.252	0.976
		Future With 10-yr Projects	3,550.03	6,825.42	0.408	0.785	254.50	7.081	0.956
		Reduction (10-year Plan)	-6%	-5%	-6%	-5%	-2%	-2%	-2%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	254.504	7.081	0.956
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-2%	-2%	-2%
Lower Sugarland WMA	3,743	Existing Condition	543.58	1,297.11	0.063	0.149	97.73	2.399	0.352
		Future Without Projects	581.80	1,402.64	0.067	0.161	98.00	2.424	0.356
		Future With 10-yr Projects	550.30	1,357.72	0.063	0.156	95.06	2.380	0.348
		Reduction (10-year Plan)	-5%	-3%	-5%	-3%	-3%	-2%	-2%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	93.27	2.36	0.34

Table 6.1
Sugarland Run Pollutant Loading and Flow Reductions by WMA

WMA	Area (ac)	Scenario[3]	Runoff Volume (in/yr)[1]		Peak Flow (cfs/ac)[1]		TSS (lb/ac/yr)[2]	TN (lb/ac/yr)[2]	TP (lb/ac/yr)[2]
			2 Year	10 Year	2 Year	10 Year			
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-5%	-3%	-4%
Lower Middle Sugarland WMA	3,503	Existing Condition	296.59	627.33	0.034	0.072	188.88	4.509	0.669
		Future Without Projects	356.95	800.81	0.041	0.092	191.04	4.586	0.678
		Future With 10-yr Projects	351.46	792.84	0.040	0.091	185.93	4.522	0.666
		Reduction (10-year Plan)	-2%	-1%	-2%	-1%	-3%	-1%	-2%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	179.62	4.46	0.65
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-6%	-3%	-4%
Potomac WMA[4]	1,053	Existing Condition	1,649.94	3,824.07	0.190	0.440	74.65	1.473	0.226
		Future Without Projects	1,649.94	3,824.07	0.190	0.440	74.66	1.474	0.226
		Future With 10-yr Projects	1,649.94	3,824.17	0.190	0.440	74.64	1.473	0.226
		Reduction (10-year Plan)	0%	0%	0%	0%	0%	0%	0%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	74.64	1.47	0.23
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	0%	0%	0%
Upper Sugarland WMA	928	Existing Condition	3,398.88	6,772.61	0.391	0.779	386.02	9.049	1.236
		Future Without Projects	3,584.49	7,039.15	0.412	0.810	408.79	9.605	1.296
		Future With 10-yr Projects	3,363.16	6,688.95	0.387	0.769	389.12	9.341	1.257
		Reduction (10-year Plan)	-6%	-5%	-6%	-5%	-5%	-3%	-3%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	372.26	9.17	1.23
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-9%	-4%	-5%
Upper Middle Sugarland WMA	1,975	Existing Condition	2,121.30	4,394.20	0.244	0.505	258.78	6.699	0.967
		Future Without Projects	2,413.53	5,142.53	0.278	0.592	261.31	6.741	0.971
		Future With 10-yr Projects	2,286.22	4,854.19	0.263	0.558	235.88	6.429	0.918
		Reduction (10-year Plan)	-5%	-6%	-5%	-6%	-10%	-5%	-6%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	229.29	6.36	0.91
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-12%	-6%	-7%

[1] Flow is cumulative.
[2] Loads are representative of individual land area contributions.
[3] 25-year projects were not evaluated in the hydrologic model.
[4] No projects were proposed in this WMA.

Table 6.2 Sugarland Run Overall Pollutant Loading and Flow Reductions									
Watershed	**Area (ac)**	**Scenario[2]**	**Runoff Volume (in/yr)[1]**		**Peak Flow (cfs/ac)[1]**		**TSS (lb/ac/yr)**	**TN (lb/ac/yr)**	**TP (lb/ac/yr)**
			2 Year	**10 Year**	**2 Year**	**10 Year**			
Sugarland Run	14,407	Existing Condition	613.11	1,447.72	0.071	0.167	198.83	4.850	0.702
		Future Without Projects	649.40	1,550.05	0.075	0.178	202.51	4.952	0.714
		Future With 10-yr Projects	619.74	1,506.90	0.071	0.173	194.18	4.835	0.695
		Reduction (10-year Plan)	-5%	-3%	-5%	-3%	-4%	-2%	-3%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	188.65	4.78	0.68
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-7%	-4%	-4%

[1] Flow is cumulative.
[2] 25-year projects were not evaluated in the hydrologic model.

Based on modeling results, implementation of the restoration strategies and projects described in the 10-year plan will result in reductions in stormwater runoff flows and pollutant loads. The values shown in these tables have all been normalized to the drainage area and the reductions shown here indicate reductions per unit area. The model results show the greatest reductions in WMAs further upstream such as the Headwaters, Upper Sugarland and Upper Middle Sugarland WMAs where stormwater management generally has the greatest effect and where projects have been prioritized. WMAs where no projects or restoration strategies are proposed such as Potomac WMA, which is located completely within Loudoun County, are shown in Table 6.1 above without any reductions or increases in pollutant loadings or stormwater flow.

6.2.2 Horsepen Creek

Tables 6.3 and 6.4 below summarize the results of the pollutant and hydrologic models in terms of pollutant loading and stormwater flow reductions for the Horsepen Creek Watershed. All values were normalized to the drainage area to allow for direct and accurate comparisons. Runoff volume and peak flow values were obtained from SWMM hydrologic models and were calculated cumulatively. In other words, flows were summed from upstream to downstream and were divided by the total contributing drainage area. Total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) values were obtained from the results of the STEPL pollutant models. These values were calculated based on the individual land area contributions and may not increase from upstream to downstream.

Table 6.3
Horsepen Creek Pollutant Loading and Flow Reductions by WMA

WMA	Area (ac)	Scenario[3]	Runoff Volume (in/yr)[1]		Peak Flow (cfs/ac)[1]		TSS (lb/ac/yr)[2]	TN (lb/ac/yr)[2]	TP (lb/ac/yr)[2]
			2 Year	10 Year	2 Year	10 Year			
Cedar Run WMA	782	Existing Condition	2,470.81	5,342.51	0.284	0.615	264.86	6.11	0.924
		Future Without Projects	2,497.59	5,393.07	0.287	0.620	265.79	6.14	0.928
		Future With 10-yr Projects	2,270.70	5,002.40	0.261	0.575	225.25	5.77	0.849
		Reduction (10-year Plan)	-9%	-7%	-9%	-7%	-15%	-6%	-9%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	212.69	5.66	0.82
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-20%	-8%	-11%
Frying Pan WMA	1,130	Existing Condition	1,893.41	4,060.69	0.218	0.467	232.42	6.68	0.954
		Future Without Projects	2,523.19	5,297.10	0.290	0.609	243.22	6.96	0.990
		Future With 10-yr Projects	2,164.66	4,591.34	0.249	0.528	225.31	6.73	0.953
		Reduction (10-year Plan)	-14%	-13%	-14%	-13%	-7%	-3%	-4%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	224.95	6.73	0.95
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-8%	-3%	-4%
Indian Creek WMA[4]	2,066	Existing Condition	1,883.67	4,184.63	0.217	0.481	139.27	3.49	0.495
		Future Without Projects	1,883.51	4,184.26	0.217	0.481	139.27	3.49	0.495
		Future With 10-yr Projects	1,883.51	4,184.26	0.217	0.481	139.27	3.49	0.495
		Reduction (10-year Plan)	0%	0%	0%	0%	0%	0%	0%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	139.27	3.49	0.50
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	0%	0%	0%
Lower Horsepen WMA[4]	3,190	Existing Condition	1,176.07	2,625.44	0.135	0.302	278.98	5.00	0.607
		Future Without Projects	1,342.96	2,972.98	0.154	0.342	278.98	5.00	0.607
		Future With 10-yr Projects	1,327.85	2,925.21	0.153	0.336	278.98	5.00	0.607
		Reduction (10-year Plan)	-1%	-2%	-1%	-2%	0%	0%	0%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	278.98	5.00	0.61
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	0%	0%	0%
Lower Middle Horsepen WMA	1,186	Existing Condition	1,174.06	2,715.91	0.136	0.315	369.06	8.23	1.249
		Future Without Projects	1,533.81	3,301.16	0.178	0.383	375.40	8.44	1.277
		Future With 10-yr Projects	1,506.72	3,164.54	0.175	0.367	349.10	8.08	1.220
		Reduction (10-year Plan)	-2%	-4%	-2%	-4%	-7%	-4%	-4%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	344.10	8.07	1.21

Table 6.3
Horsepen Creek Pollutant Loading and Flow Reductions by WMA

WMA	Area (ac)	Scenario[3]	Runoff Volume (in/yr)[1]		Peak Flow (cfs/ac)[1]		TSS (lb/ac/yr)[2]	TN (lb/ac/yr)[2]	TP (lb/ac/yr)[2]
			2 Year	10 Year	2 Year	10 Year			
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-8%	-4%	-5%
Merrybrook WMA	967	Existing Condition	3,518.40	6,938.40	0.405	0.798	118.66	4.75	0.707
		Future Without Projects	4,655.22	8,571.15	0.535	0.986	130.53	5.42	0.782
		Future With 10-yr Projects	4,542.89	8,404.31	0.523	0.967	129.54	5.40	0.776
		Reduction (10-year Plan)	-2%	-2%	-2%	-2%	-1%	0%	-1%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	128.40	5.36	0.77
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-2%	-1%	-1%
Middle Horsepen WMA	953	Existing Condition	1,040.98	2,784.46	0.120	0.320	260.25	5.70	0.707
		Future Without Projects	1,155.55	2,905.34	0.133	0.334	327.62	7.25	0.859
		Future With 10-yr Projects	1,087.15	2,855.62	0.125	0.328	323.05	7.04	0.837
		Reduction (10-year Plan)	-6%	-2%	-6%	-2%	-1%	-3%	-3%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	289.88	6.79	0.80
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-12%	-6%	-7%
Stallion WMA[4]	2,394	Existing Condition	1,150.72	2,571.28	0.132	0.296	132.50	2.31	0.292
		Future Without Projects	1,150.72	2,571.28	0.132	0.296	132.50	2.31	0.292
		Future With 10-yr Projects	1,150.72	2,571.28	0.132	0.296	132.50	2.31	0.292
		Reduction (10-year Plan)	0%	0%	0%	0%	0%	0%	0%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	132.50	2.31	0.29
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	0%	0%	0%
Upper Horsepen WMA	1,929	Existing Condition	1,089.50	3,050.78	0.125	0.351	180.09	4.800	0.694
		Future Without Projects	1,110.70	3,092.65	0.128	0.356	182.94	4.876	0.702
		Future With 10-yr Projects	1,024.87	3,034.59	0.118	0.349	133.24	4.575	0.642
		Reduction (10-year Plan)	-8%	-2%	-8%	-2%	-27%	-6%	-9%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	132.25	4.58	0.64
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-28%	-6%	-9%

[1] Flow is cumulative.
[2] Loads are representative of individual land area contributions.
[3] 25-year projects were not evaluated in the hydrologic model.
[4] No projects were proposed in this WMA.

Table 6.4 Horsepen Creek Overall Pollutant Loading and Flow Reductions									
Watershed	**Area (ac)**	**Scenario[2]**	**Runoff Volume (in/yr)[1]**		**Peak Flow (cfs/ac)[1]**		**TSS (lb/ac/yr)**	**TN (lb/ac/yr)**	**TP (lb/ac/yr)**
			2 Year	**10 Year**	**2 Year**	**10 Year**			
Horsepen Creek	14,597	Existing Condition	1,176.07	2,625.44	0.135	0.302	213.24	4.80	0.660
		Future Without Projects	1,342.96	2,972.98	0.154	0.342	220.20	4.99	0.682
		Future With 10-yr Projects	1,327.85	2,925.21	0.153	0.336	207.57	4.87	0.660
		Reduction (10-year Plan)	-1%	-2%	-1%	-2%	-6%	-2%	-3%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	204.09	4.85	0.66
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	-7%	-3%	-4%

[1] Flow is cumulative.
[2] 25-year projects were not evaluated in the hydrologic model.

Based on modeling results, implementation of the restoration strategies and projects described in the 10-year plan will result in reductions in stormwater runoff flows and pollutant loads. The values shown in these tables have all been normalized to the drainage area and the reductions shown here indicate reductions per unit area.

The model results show the greatest reductions in WMAs further upstream such as the Cedar Run, Frying Pan and Upper Horsepen WMAs where stormwater management generally has the greatest effect and where projects have been prioritized. WMAs where no projects or restoration strategies are implemented such as the Indian Creek and Stallion WMAs, which are both located completely within Loudoun County, are shown in Table 6.3 above without any reductions or increases in pollutant loadings or stormwater flow. Lower Horsepen WMA is also located completely within Loudoun County and no projects are proposed within its boundaries. STEPL results for pollutant loadings show no reductions or increases; however the flow values do indicate a reduction. Stormwater flow values were calculated cumulatively as described previously. Since Lower Horsepen WMA is the downstream most WMA in the Horsepen Run watershed and located on the main stem of Horsepen Run, the flow values shown in Table 6.3 for this WMA reflect flow reductions for the entire Horsepen Run watershed.

6.3 Project Costs and Benefits Analysis

An integral element to evaluating the benefits of restoration strategies and projects is associated costs. Cost estimates were calculated for all structural projects detailed in previous sections. Detailed cost estimates, as shown on the project fact sheets, were determined for structural projects in the 0-10 year implementation phase. The total costs of implementing projects in this phase were calculated to be approximately $17 million and $12.6 million for the Sugarland Run and Horsepen Creek watersheds, respectively. Associated costs for structural projects in the 11-25 year implementation phase were roughly approximated based on the overall costs associated with similar projects in the 10 year implementation plan and are estimated at approximately $13 million. Cost estimates were not calculated for non-structural projects, as they do not require traditional construction measures to be implemented and may be programmatic in nature. The 10-year implementation plan consists of 70 total structural projects. The 11-25 year

implementation plan consists of 50 additional structural projects. There are 19 non-structural projects identified in the plan. The total cost for all structural projects in the plan is $43 million.

In addition to the calculation of cost estimates for projects listed in the implementation plan, a cost benefit analysis was also performed. The project cost distribution for all projects listed in the 10-year implementation plan was evaluated. The evaluation of the project cost distribution allowed for a determination of outliers within the lists of projects. These outliers could be projects that were significantly more or less expensive than other projects in the lists. These projects were further scrutinized and evaluated to determine if they should remain in the 10-year list. Outliers determined to be kept in the list were evaluated separately from the other projects in the 10-year list. A cost to benefit ratio was calculated based on the subwatershed ranking composite score and the projects' associated costs. Using the cost to benefit ratio, all structural projects in the 10-year implementation plan were reordered based on this analysis.

6.4 Overall Costs and Benefits of Plan Implementation

The stormwater modeling and costs and benefits analysis described in this section demonstrates the value of the projects and restoration strategies discussed within the plan. The overall cost of implementing all the projects on the 10-year list is $30 million. Implementation of all projects and restoration strategies in the 10-year priority list will result in significant overall reductions in stormwater flows and pollutant loads, as shown in Table 6.5. Stormwater runoff volume from the 2-year and 10-year storm events would decrease by 2 percent or 45 inches per year and 91 inches per year, respectively. The peak flow rate would also decrease by 2 percent, resulting in a reduction of 0.005 CFS per acre for the 2-year storm event and 0.010 CFS per acre for the 10-year storm event. Total suspended solids would be reduced by 7 percent overall or 420,419 pounds per year. Total nitrogen would be reduced by 2 percent or 3,551 pounds per year and total phosphorus would be reduced by 3 percent or 625 pounds per year.

Implementation of all projects within the plan, including projects in the 25-year implementation plan will result in additional reductions in stormwater flows and pollutant loads. Total suspended solids would be reduced by 9 percent overall or 550,887 pounds per year. Total nitrogen would be reduced by 3 percent or 4,747 pounds per year and total phosphorus would be reduced by 4 percent or 850 pounds per year.

Table 6.5
Overall Pollutant Loading and Flow Reductions

Watershed	Area (ac)	Scenario[2]	Runoff Volume (in/yr)[1]		Peak Flow (cfs/ac)[1]		TSS (lb/ac/yr)	TN (lb/ac/yr)	TP (lb/ac/yr)
			2 Year	10 Year	2 Year	10 Year			
Sugarland Run and Horsepen Creek	29,004	Existing Condition	1,789.17	4,073.16	0.21	0.47	206.09	4.82	0.68
		Future Without Projects	1,992.35	4,523.03	0.23	0.52	215.41	4.98	0.70
		Future With 10-yr Projects	1,947.59	4,432.10	0.22	0.51	200.92	4.85	0.68
		Reduction (10-year Plan)	-2%	-2%	-2%	-2%	-7%	-2%	-3%
		Future With 0-25 yr Projects	N/A	N/A	N/A	N/A	196.42	4.81	0.67
		Reduction (25-year Plan)	N/A	N/A	N/A	N/A	9%	3%	4%

[1] Flow is cumulative.
[2] 25-year projects were not evaluated in the hydrologic model.