Assessment of BMP Cost-effectiveness

Cost-effectiveness indicates the pollutant load reduction per dollar spent on installing and maintaining BMPs. The cost-effectiveness of a BMP was measured by the ratio of the pollutant load reduction to the annual average cost of establishing and maintaining the BMP in Neshanic River Watershed. The project team developed the detailed information about individual BMPs at specific sites in the watershed or for representative farms. Information for individual BMP projects is scaled up to estimate watershed reductions in TP and sediment, and the total and annual costs at the watershed scale. The cost effectiveness of these BMPs in reducing TP and sediment is calculated by dividing the annual watershed cost by the reduction in TP and sediment.

Table 1 summarizes the water quality effects, the costs and cost-effectiveness of the agricultural BMPs in Neshanic River Watershed assuming each BMP is individually applied to suitable land types in the watershed. The scale-up for cover crops, riparian buffers, prescribed grazing, livestock access control, contour farming and nutrient management are based on the information in the agricultural BMP detail sheets developed by the project team. Information on the assessment unit, reduction in TP and sediment, assessment costs and land type suitable for BMP implementation are taken from the agricultural project descriptions given in the detail sheets. Reductions in TP and sediment for the agricultural BMPs are based on the reduction rates from literature, the SWAT-estimated pollutant loads, and the land suitable for BMP implementation as specified in Table 1. Total watershed costs are the product of total assessment costs and the applicable unit divided by the assessment unit. The assessment unit is the acreage of a representative farm used for estimating the BMP implementation cost. The applicable unit is the total acreage of the agricultural lands the BMP can be potentially applied to.

The total watershed costs are calculated based on the life span of the BMPs. Water quality effects are measured by the annual average reduction in TP and sediment. The cost-effectiveness of these BMPs is based on the annual watershed costs of these BMPs estimated based on the following assumptions. First, the implementation costs for cover crops, contour farming and nutrient management are estimated assuming farmers enter into three-year contracts to maintain the BMPs once enrolled in the programs. Second, life spans are five years for the facilities used in prescribed grazing and ten years for livestock access control. After the initial program period, farmers are assumed to continue using those practices due to the added economic benefits, their increased environmental awareness and tighter regulatory requirements. Third, the lifespan for riparian buffers and conservation buffers is assumed to be 15 years.

The annual watershed cost equals the total watershed cost divided by the years in the effective assessment period plus annual operation and maintenance costs, if any. Cost-effectiveness for TP reduction equals the annual average TP reduction divided by the annual watershed cost. Cost-effectiveness for sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Therefore, cost-effectiveness measures the reduction in TP or sediment per $1,000 spent on the BMP in the watershed. For example, every $1,000 of expenditure would reduce TP by 1.86 pounds if spent on cover crops and 32.08 pounds if spent on livestock access control. BMPs were prioritized based on their cost-effectiveness with BMPs resulting in a larger reduction in pollutant load receiving a higher priority for implementation.

Table 1: Water quality effects, costs and cost-effectiveness of agricultural BMPs in the Neshanic River Watershed

		Cover Crop	Presc. Grazing	Access Control	Contour Farming	Nutrient Mgmt.	Conser. Buffers
1	Assessment Unit	62 acres	30 acres	500 feet	62 acres	62 acres	3 acres
2	TP Reduction Rate (%)	15	25	60	20	47	50
3	Sediment Reduction Rate (%)	20	25	75	40	0	50
4	Installation Cost ($)	18,526	9,576	2,868	5,580	5,580	9,132
5	Maintenance Cost ($)			1,000			3,750
6	Other Costs ($)	1,000	3,750	1,900	1,650	1,650	5,200
7	Total Assessment Unit Cost ($)	19,526	13,326	5,768	7,230	7,230	18,082
8	Land Type Suitable for BMP	Row crops	Pasture	Riparian areas of pasture	Row Crops	Crops, hay, pasture	HASs
9	Applicable Unit	4,011 acres	892 acres	24,663 feet	1,846 acres	7,645 acres	988 acres
10	Annual TP Reduction (lbs)	784	380	913	507	3,478	3,700
11	Annual Sediment Reduction (tons)	79	16	52	73	0	250
12	Total Watershed Cost ($)	1,263,180	396,226	284,512	215,267	891,548	5,955,005
13	Lifespan of BMP (years)	3	5	10	3	3	15
14	Annual Watershed Cost ($)	421,060	79,245	28,451	71,756	297,183	397,000
15	Cost-eff. of TP Reduction (lbs/$1,000)	1.861	4.799	32.083	7.066	11.703	9.320
16	Priority Rank for TP Reduction	6	5	1	4	2	3
17	Cost-eff. of Sed. Reduction (T/$1,000)	0.188	0.198	1.842	1.016		0.630
18	Priority Rank for Sed. Reduction	5	4	1	2	6	3

Table 1 gives the priority ranks for BMPs in reducing TP and sediment. Livestock access control is ranked first in reducing both TP and sediment. Nutrient management is ranked second in reducing TP and contour farming is ranked second in reducing sediment. Conservation buffer and contour farming are ranked third and fourth, respectively, in reducing TP whereas conservation buffers and prescribed grazing are ranked third and fourth, respectively, in reducing sediment. The cost-effectiveness indicates the order in which BMPs should be selected to reduce pollutant loads when there is a limited budget for watershed restoration. Pollution load reductions are estimated assuming BMPs are applied individually. When multiple BMPs are applied to the same fields, the pollutant reduction from those fields will increase, but the total reduction in pollutant loads at the watershed scale is expected to be smaller because of the overlapping effects.

Table 2 presents the resulting water quality effects, costs and cost-effectiveness for stormwater BMPs in Neshanic River Watershed. Estimation of the effects assumes each BMP is individually applied to suitable agricultural lands in the watershed. The watershed has 3,545 potential sites for rain gardens and 27,603 feet of riparian segments suitable for vegetative buffers in the non-agricultural, developed lands. The stormwater infrastructure inventory identified 853 segments of roadside swales and ditches with an average length of 240 feet and 153 detention basins with the average size of 0.68 acres. The scale-up for rain gardens, roadside ditch retrofitting, detention basin retrofitting and vegetative buffers in developed lands is based on the information in the stormwater BMP detail sheets on the site specific projects. Information on the assessment unit, reduction rates for TP and sediment, and assessment costs come from the project descriptions given in those detail sheets. Specifically, the information on individual rain gardens is used to estimate the water quality impacts and watershed costs for all 3,545 rain gardens in the watershed. Because its size is close to the average size of ditches in the watershed, information for retrofitting roadside Ditch_SD_389 was scaled up to estimate the impacts of retrofitting all ditches. The scale-up for detention basins is adjusted using the information on retrofitting DB_MDB_0035. Information on the vegetative buffer project was used to scale up to the watershed effects of installing 27,603 feet of buffers in the non-agricultural developed lands. Total annual reductions in TP and sediment are the products of the reductions achieved by individual projects and the applicable units divided by the assessment unit. The total watershed cost is the product of the total assessment cost and the applicable units divided by the assessment unit. The lifespans for all stormwater BMPs are assumed to be 15 years. Annual watershed cost is total watershed cost divided by 15 years, which is the life span of the BMPs.

Similarly, the cost-effectiveness of TP reduction is the annual average TP reduction divided by the annual watershed cost for each stormwater BMP. Cost-effectiveness of sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Cost-effectiveness measures the average reduction in TP or sediment per $1,000 of expenditure on each stormwater BMP in the watershed. For example, if $1,000 is spent on vegetative buffers on developed lands, TP would decrease by 4.32 pounds and sediment would decline by 2.16 tons. Rain gardens would only reduce TP by 0.045 pounds and sediment by 0.004 tons per $1,000 spent on each practice. BMPs were prioritized based on their cost-effectiveness. The BMPs resulting in a larger reduction in pollutant load are given a higher priority for implementation.

Table 2 gives the priority ranks for these stormwater BMPs in reducing TP and sediment, respectively. Priority ranks for reducing TP and sediment are the same for the four stormwater BMPs. Vegetative buffers and the detention basin retrofitting are ranked first and second, respectively, and the roadside ditch retrofitting and rain gardens are ranked third and fourth, respectively, in reducing TP and sediment. There are dramatic differences in the cost-effectiveness of the four stormwater BMPs. Detention basin retrofitting is almost as cost-effective as the vegetative buffers in reducing TP. Rain gardens are almost 100 times more cost effective than vegetative buffers in reducing TP. A comparison of the cost effectiveness of stormwater and agricultural BMPs indicated that all stormwater BMPs except vegetative buffers are much more expensive than the agricultural BMPs in reducing TP and sediment.

Table 2: Water quality effects, costs and cost-effectiveness of stormwater BMPs in Neshanic River Watershed

		Rain Garden	Roadside Ditch Retrofitting	Detention Basin Retrofitting	Vegetative Buffers on Developed Lands
1	Assessment Unit	1 unit	1 unit	1 unit	1,900 feet
2	TP Reduction Rate (%)	50	30	50	30
3	Sediment Reduction Rate (%)	90	60	90	60
4	Installation Cost ($)	1,650	13,000	17,000	6,200
5	Maintenance Cost ($)	1,500	7,500	7,500	1,500
6	Other Costs ($)	1,000	3,000	5,000	1,500
7	Total Assessment Cost ($)	4,150	23,500	29,500	9,200
8	Applicable Unit	3,545 units	853 units	153 units	27,603 feet
9	Annual TP Reduction (lbs.)	44	196	1102	38
10	Annual Sediment Reduction (tons)	4	33	138	19
11	Total Watershed Costs ($)	14,711,750	20,045,500	4,513,500	133,657
12	Life span of BMP (years)	15	15	15	15
13	Annual Watershed Cost ($)	980,783	1,336,367	300,900	8,910
14	Cost-eff. for TP Reduction (lbs./$1,000)	0.045	0.147	3.661	4.321
15	Priority Rank for TP Reduction	4	3	2	1
16	Cost-eff. for Sediment Reduction (T/$1,000)	0.004	0.025	0.458	2.160
17	Priority Rank for Sediment Reduction	4	3	2	1

All BMPs have other hydrological and water quality benefits. For example, stormwater BMPs, such as rain gardens, result in large reductions in the amount of stormwater runoff and runoff velocity in receiving streams. One of the most significant water quality issues in the Neshanic River Watershed is pathogenic contamination. The SWAT model indicates that failing OSDSs contribute 46 percent of the pathogenic load, animal manure applied to row-crop fields contributes 31 percent of the annual pathogenic load to Neshanic streams, and livestock access to streams contributes 19 percent of the annual pathogenic load in the Neshanic River Watershed. Fate and transport of pathogens are not as well understood as fate and transport of TP and sediment. Therefore, the effectiveness of the BMPs in reducing pathogenic loads to the streams cannot be assessed as precisely as reductions in TP and sediment. Cost-effectiveness of BMPs for reducing the pathogenic loads was assessed differently.

Table 3 gives the costs of three BMPs for reducing pathogenic loads: OSDS management, manure management and livestock stream access control. OSDS management involves two integral components of the OSDS education and management strategies: system inspection and maintenance; and failing system retrofitting. Total cost of OSDS management is $7.6 million and annual cost is $745,000. Improving OSDS management in the watershed will reduce pathogenic loads to streams by 46 percent at an annual average cost of $16,196 for each 1 percent reduction in pathogenic load. Manure management includes establishing and operating 5 regional animal waste storage and composting structures and implementing manure application incorporation technology for row-crop fields in the watershed, in addition to being compliant with the New Jersey Animal Waste Rules. Total cost for the two BMP projects for manure management is $501,480 and the annual cost is $96,480. Manure management is expected to reduce pathogenic loads to streams from manure application by 31 percent. The cost of reducing pathogenic loads by 1 percent is $3,112 for manure management. As discussed before, the annual cost of livestock stream access control is $28,451; such control will reduce pathogenic loads to streams in the watershed by 19 percent. The cost of reducing pathogen loads to streams by 1 percent is $1,497 for the livestock access control practice. In summary, livestock access control, manure management and OSDS management are the highest, second highest and lowest cost-effective BMPs for reducing the pathogenic loads, respectively.

Table 3: Costs of three major BMPs for reducing pathogenic loads in Neshanic River Watershed

Types of BMPs	Applicable Units	Unit Costs ($/unit)	Life span (years)	Total Cost ($)	Annual Cost ($/year)
OSDS Management					
System Inspection and Maintenance	1,490 units	600	3	894,000	298,000
Retrofitting on Failed Systems	447 units	15,000	15	6,705,000	447,000
Subtotal				7,599,000	745,000
Manure Management					
Regional Anima Waste Storage and composting Structure	5 units	90,000	10	450,000	45,000
Manure Application Incorporation Technology	330 acres	156	1	51,480	51,480
Subtotal				501,480	96,480
Livestock Stream Access Control					
Livestock Access Control	24,663 feet	11.54	10	284,512	28,451
Subtotal				284,512	28,451

Table 4 summarizes the priority ranks of all BMP projects in terms of their cost-effectiveness in reducing TP, sediment and pathogens in the Neshanic River Watershed. The highest-ranked BMP in terms of cost-effectiveness has the highest priority for implementation. The top 5 ranked BMPs for reducing TP loads are:

1. Livestock access control;
2. Nutrient management;
3. Conservation buffers on agricultural lands;
4. Contour farming; and

5. Prescribed grazing.

The top 5 ranked BMPs for reducing sediment are:

1. Vegetative buffers in developed lands;
2. Livestock access control;
3. Contour farming;
4. Conservation buffers on agricultural lands; and
5. Detention basin retrofitting.

The top 5 ranked BMPs for reducing pathogenic loads to the streams are

1. Livestock access control;
2. Livestock waste storage and composting structures;
3. OSDS inspection and maintenance;
4. Manure application incorporation technology; and
5. Failed OSDS retrofitting.

Table 4: Priority ranks for all BMP projects in Neshanic River Watershed

BMP Project		Priority Rank in Reducing		
		TP	Sediment	Pathogens
1	Cover Crops	8	7	
2	Prescribed Grazing	5	6	6
3	Livestock Access Control	1	2	1
4	Contour Farming	4	3	
5	Nutrient Management	2		9
6	Conservation Buffers in Agricultural Lands	3	4	10
7	Livestock Waste Storage and Composting Structure	12		2
8	Manure Application Incorporation Technology	11		4
9	Rain Gardens	10	9	
10	Road Ditches	9	8	11
11	Detention Basin Retrofitting	7	5	7
12	Vegetative Buffers on Developed Lands	6	1	8
13	OSDS Inspection and Maintenance	13		3
14	Failed OSDS Retrofitting	14		5

Note: A shaded area indicates the BMP has an insignificant impact on the reduction of the pollutant.

Additional criteria can be used to rank BMP projects. These criteria may include

- Landowner access and cooperation;
- Permitting requirements;
- Site constraints (topography, wetlands, stream encroachment, etc);
- Funding sources;
- Expected time frames;
- Project partners needed;
- Ecological benefits; and
- Long term maintenance/monitoring needs.

Use of those criteria needs more site-specific information. Although they cannot be used in the plan to rank the BMPs due to the limited site-specific information, they can be used to rank any proposed implementation projects when more site-specific information is collected for implementation.