Chapter 3
Pollutant Loading Analysis

3.1 Pollutants of Concern

As previously discussed in Chapter 2, the main pollutants of concern in the Nippersink Creek watershed include fecal coliform, nutrients and sediment. The main sources of these pollutants are non-point sources. The segment of the main channel downstream of Wonder Lake is included on the IEPA 303(d) list for fecal coliform impairment. There are also indications that low-streamflow conditions could result in seasonal dissolved oxygen (DO) problems, stressing aquatic organisms. Since the watershed is still primarily rural, the main sources of non-point pollutant loads are nutrients and sediment from agricultural runoff. Another source of sediment and nutrients is streambank erosion from within channelized or heavily shaded / poorly vegetated stream segments.

Urban runoff from the developed areas around Woodstock, Richmond, Spring Grove, Hebron and Wonder Lake also contribute significant amounts of pollutants associated with urban runoff, such as oils and grease, heavy metals, and increased water temperature. Current water quality conditions are excellent; however, rapid and poorly planned development poses the main threat to future water quality in the watershed.

3.1.1 Pollutant Loading Analysis Approach

A pollutant loading analysis was performed to identify and quantify the watershed sources of pollutants. The analysis results were then used to identify management strategies for addressing existing and future water quality concerns resulting from human activities. The results of this analysis indicated problem areas or 'hot spots' under existing and future land use conditions.

Because of the limited amount of water quality data available in the watershed, sophisticated modeling approaches were not used. A GIS-based Generalized Watershed Loading Function (GWLF) (http://www.avgwlf.psu.edu/overview.htm) model was used to estimate the pollutant loads for the 14 subwatersheds. This model uses readily available watershed specific characteristics such as land cover, topography, soil types and meteorology to estimate pollutant loads. GWLF output consists of monthly averaged pollutant loads from which seasonal trends can be discerned.

The GWLF analysis is somewhat more realistic than the commonly used "Simple Method" or export-coefficient spreadsheet based pollutant loading techniques in that the GWLF simulation incorporates seasonality, groundwater, and streambank erosion directly into the simulation.

In addition, the GWLF model uses monthly precipitation values to determine monthly runoff volumes. In this way, the model is capable of reproducing pollutant loads production in the watershed more realistically.

Another advantage of the GWLF model is that it can also be used to determine the effectiveness of either existing or proposed Best Management Practices (BMP's) in reducing future pollutant loads. This capability of the GWLF model provides some verification that the BMP's can indeed reduce pollutant load. This function was used to generate the pollutant load reductions described in the subwatershed reports.

To determine the pollutant load reduction for a particular BMP, the GWLF model aggregates similar BMP's within the subject subwatershed to calculate the total pollutant load reduction. For example, the pollutant load reduction resulting from applying nutrient management is calculated by the total number of acres included, and not by the number of individual farm units. This procedure is in accordance with the Supplemental Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories in FY 2003. http://www.epa.gov/nps/Section319/319guide03.html.

There are a number of other procedures that the EPA has developed for determining load reductions (See: http://it.tetratech-ffx.com/stepl/STEPLmain_files/LoadReductionModels.pdf for a comprehensive description). The STEPL method was developed by USEPA and is spreadsheet based, and calculates the combined load reduction resulting from a variety of BMP's. The other commonly used model is the USEPA Region 5 spreadsheet model which calculates the load reduction for each individual BMP at the source level. The simple spreadsheet approach was used to calculate BMP fecal coliform reductions that the GWLF model cannot explicitly simulate. For some BMP's, such as outreach and regulatory programs, load reductions were assigned conservative values based on literature and professional judgment.

3.1.2 Pollutant Loading Analysis Methodology

The Illinois Department of Natural Resources (IDNR) 1999 land cover data was enhanced with a 2005 aerial photograph of the Nippersink Creek watershed and used for the GWLF analysis. The GWLF model uses nine categories of land cover. Since some of the land use data had more categories than those used in the GWLF model, some land use maps were aggregated to produce the required nine categories. Table 1 in the report appendix presents the assignment of the available land uses into these nine land uses.

The following nine land use categories were used in the analysis:

- Wetlands
- Forest
- Hay/Pasture
- Row Crops
- Low Density Development (≤ 1unit per 1.2 acres)
- High Density Development (≥ 1 unit per 1.2 acres)
- Transitional/Quarries
- Turfgrass/Golf Course
- Water

The United States Geological Survey (USGS) operates station 05550300 in Elgin, Illinois with records of precipitation from October 1, 1998 to present. Daily precipitation records from this station were used in the Nippersink Creek GWLF model. The records defined a five-year period used in estimating the averaged monthly precipitation and pollutant load for each Nippersink subwatershed.

Maximum and minimum daily temperatures are also required for GWLF models. Records from the Meteorological Site at Argonne National Laboratory, Illinois (USGS station 414204087594201) were used for the five-year period modeled. Although this site is outside the Nippersink Creek watershed, the records are representative of the temperatures over the study area.

The topography and soil types of Nippersink Creek Watershed were defined by the USGS digital Elevation Model and USDA-NRCS Soil Survey of McHenry County, respectively (USDA-NRCS, 1995).

The GWLF model was used to generate two scenarios for each subwatershed:

- the existing conditions in the watershed, and
- future year 2030 developed conditions.

Projections of future land use were generated using various sources of maps including municipal sources and information from the ***McHenry County 2030 Comprehensive Plan*** that is being developed.

The pollutants analyzed by the GWLF model are sediment and nutrients (nitrogen and phosphorus). These pollutants may be considered surrogates for a variety of pollutants generated in typical rural and urban settings. Urban runoff, however, contains additional pollutants such as oils and grease, heavy metals, and elevated temperatures. Sediment is a good surrogate for both urban and agricultural runoff because sediment particles are vehicles for transporting a variety of pollutants such as heavy metals, nutrients, oils and grease.

Fecal Coliform Loading

Fecal coliform concentrations are very variable and unless the key sources of these bacteria are known, an effective pollutant reduction strategy cannot be implemented. Fecal coliform loads may be computed by a simple export-coefficient procedure. However, such information is of little use in addressing the impairment concern if the sources of the predicted loads are not known. The IEPA Integrated Water Quality Report and Section 303(d) List (IEPA, 2006) did not identify the source of the fecal coliform bacteria. Urban runoff may be the main source of the high fecal coliform concentrations, but that cannot be conclusively established at this time. Additional monitoring is recommended to further isolate the sources. Typically such monitoring should include low-flow and wet-season sampling.

A load-duration curve approach (EPA, 2007) is a simple procedure for analyzing the monitoring data to determining whether the loads are from point sources or non-point sources associated with runoff events.

One other suspected source of fecal coliform is septic system failure. To evaluate whether failing septic systems are a significant source of fecal coliform, it is recommended that the McHenry County Health Department:

- Maintain records of complaints by residents of septic system problems
- Map or locate the location of failures
- Maintain a septic system permit database
- Review ordinance regarding setbacks
- Review soil data
- Inspect septic systems regularly

Once the sources of the elevated fecal concentrations are identified, then appropriate BMP's may be prescribed based on the characteristics of the sources. Appropriate BMP's or reduction measures can be prescribed such as:

- Establishing a septic system inspection program if problems with septics appear to be prevalent
- Establishing buffers around lakes
- Enforcing illicit discharge disconnections
- Controlling wildlife around natural water bodies and detention facilities by means of buffers or other devices
- Pet waste management in urban areas
- Animal feedlot and manure management along streams
- Eliminate sanitary overflows if any.

In interpreting and comparing model results, it is important to note several issues;

- A given amount of sediment from an urban development may contain a greater number of pollutants than the same amount from an agricultural area. In other words, urban sediment contains more pollutants (such as Oils & Grease, toxic metals) than sediment from agricultural areas.
- Seasonal patterns in pollutant movements are important because water quality violations generally occur seasonally. For this reason, the GWLF model can present a more realistic picture of pollutant movement in the watershed than simple event-based models which give annual loads.
- Although total pollutant loads are a good indicator of the overall cause of water quality impairments, water quality criteria/standards are based on concentrations. This is because the toxicity of a pollutant to the aquatic life is more dependent on concentrations than actual total loads.
- Contribution of point sources was small compared to non-point sources because of their small discharges.

In conclusion, annual pollutant loads are a good indicator of the potential for impairments but they should be interpreted with caution as they do not necessarily give a complete picture of the vulnerability of a watershed to impairments caused by a particular pollutant. Seasonality of the loadings is quite often a more important indicator of critical water quality conditions than the actual load amounts.

3.2 Pollutant Loading Results and Pollutant Reduction Strategies or BMP's

3.2.1 Runoff Volume

Runoff is the most critical component of any watershed process. Changes in a watershed physiographic conditions signal changes in runoff. Likewise, changes in runoff may cause profound changes in the dynamics of pollutant processes. As anticipated, the most noticeable change when a watershed urbanizes is an increased in the volume of runoff. The changes of total runoff volumes in the Nippersink watershed from existing conditions were less than 1% because of the small increase in imperviousness compared to the size of the watershed, which remains primarily rural. In individual subwatersheds such as the Wonder Lake and The Lower Elizabeth Lake Drain, runoff volumes could increase by more than 15% because of urbanization. For these watersheds, BMP's for mitigating increased runoff are recommended.

3.2.2 Best Management Practices for Runoff Reduction

The runoff reduction strategy must focus on upstream subwatersheds because the impacts from increased runoff are caused primarily by upstream runoff. Mitigation for increased runoff within the Nippersink Creek watershed can be achieved by preserving and restoring the floodplain, discouraging floodplain encroachment, and channel stabilization. Watershed wide BMP's for reducing runoff volumes are:

- Rain gardens to promote infiltration
- Preserving open lands to promote infiltration and groundwater recharge
- Practicing Low Impact Development (Reduction of imperviousness)
- Wetland conversion/restoration to encourage retention and infiltration
- Modification of tile systems.

3.2.3 Nippersink Creek Pollutant Loading Results

The following tables present results for the pollutant loading analysis under existing conditions in the Nippersink Creek subwatersheds. Also presented are projected changes of the loadings by Year 2030 based on the assumed future conditions scenarios described in the beginning of the Section. Detailed monthly loads for each subwatershed in both scenarios are included in the Appendix 2.

The existing conditions pollutant analysis results show that:

- The Vander Karr, Bailey Woods, and the Zenda Headwaters subwatersheds contribute more pollutant loads per acre than the other subwatersheds (Table 3.2)
- The Lower Nippersink Creek and Silver Creek, and Wonder Lake appear to be 'hot-spots' for fecal coliform loads
- Bailey Woods and Zenda Headwaters appear to be 'hot spots' for sediment and phosphorus loads.

The loading results reflect the predominant land use in the watershed which is row crop farming. The Bailey Woods watershed, portions of which are in Wisconsin, is about 90% farmland. The detailed model results by land use (Appendix 2) indicate that row crop farming generates a majority of the nutrient loads.

Groundwater is also an important source of nutrients loads compared to the other land uses included in the analysis. The contribution of groundwater is dependent on the soil characteristics and the amount of infiltration. The proportion of the total phosphorus load contributed by groundwater varied from 6% in the Bailey Woods subwatershed to as high as 16% in the Lower Nippersink Creek subwatershed. The contributions of groundwater to total phosphorus loads in the Glacial Park / Tamarack Farms and Silver Creek subwatersheds are also high, about 14 and 13% respectively.

The GWLF model uses soil properties and stream geomorphic features such as bank slopes, length and erodibility to estimate the contribution of stream bank erosion. The model results indicated that the contribution of bank erosion to the total sediment load varied among the subwatershed from 2% in the Zenda Headwaters to about 25% in the Lower Nippersink Creek subwatershed. About 24% of the sediment load in the Silver Creek watershed comes from stream bank erosion. Stream bank erosion in the Glacial Park / Tamarack Farms and Bailey Woods watersheds contributes about 15% and 10% respectively. These results emphasize the importance of BMP's targeted at restoring and protecting stream banks in the watershed.

The Lower Nippersink Creek, the Wonder Lake, and Silver Creek subwatersheds appear to be 'hot-spots' for fecal coliform, based on the results of the simple spreadsheet analysis. Urban runoff is suspected be the main source of fecal coliform bacteria for the Lower Nippersink Creek and Wonder Lake watersheds. Septic systems and wild life are also probable contributors for the Silver Creek watershed.

A future scenario land cover was analyzed using the GWLF model. This scenario combines the proposed comprehensive land use data from McHenry County and municipalities within Nippersink Creek was used to project a future land cover. The following assumptions were made to create this scenario:

- Assume that existing wetland will be preserved.
- Areas defined as open area in the McHenry County data will retain their existing land cover,
- Area defined as resource management area in the McHenry County data will become low density development in the future.

In general, pollutant loads remain unchanged except for the Lower Nippersink Creek, Wonder Lake, and the Lower Elizabeth Lake Drain. The results indicate reductions of total nutrient loads primarily because of the replacement of row crop with low density development. It is sometimes assumed that residential development contributes higher nutrient loads per acre than farmland, however, this is not necessarily the case (CWP, Art 4, 2002).

Based on this scenario, management strategies must focus on these future 'hot spots'. Water quality degradation would most likely occur faster in these watersheds than in the other ones.

Table 3.1: Annual Pollutant Load by Subwatershed

No.	Subwatershed	Area (acres)	Sediment		Total N		Total P		Fecal coliform	
			Existing Load (tons)	Future Trend** (%)	Existing Load (lbs)	Future Trend (%)	Existing Load (lbs)	Future Trend (%)	Existing Load (10^9 FCU)	Future Trend (%)
1	**Lower Nippersink***	**12,426**	**1,684**	**-1.2**	**49,372**	**-21.4**	**2,322**	**-40.3**	**78,152**	**+1.4**
2	Glacial Park/Tamarack	12,583	1,788	-0.6	51,666	-4.9	2,731	-8.3	70,049	+0.3
3	**Wonder Lake**	**7,881**	**1,193**	**-41.5**	**21,932**	**-29.5**	**1,791**	**-50.0**	**46,817**	**+0.9**
4	Vander Karr Creek	12,226	2,395	+1.2	45,569	-0.4	3,643	-0.3	67,289	+0.2
5	Silver Creek	12,005	1,723	+0.7	41,728	0.0	2,320	0.0	76,146	+1.5
6	Slough Creek	11,871	2,185	+1.2	46,769	0.0	3,371	0.0	65,752	+0.2
7	Bailey Woods	7,281	1,600	+1.3	31,571	0.0	2,562	0.0	39,952	+0.1
8	Nippersink Headwaters	6,594	916	+4.2	27,624	0.0	1,496	0.0	36,495	+0.2
9	Zenda Headwaters	4,315	2,495	+1.7	23,049	0.0	3,647	0.0	24,961	+0.7
10	North Branch Nippersink	6,754	1,143	+1.0	24,015	-5.3	1,713	-7.8	39,526	+0.8
11	Elizabeth Lake	3,078	463	-35.7	11,384	-29.9	733	-49.1	17,474	+0.5
12	Upper North Branch Nippersink	4,493	541	+8.6	7,662	0.0	819	0.0	18,348	+0.9
13	**Lower Elizabeth Lake Drain**	**24,540**	**4,582**	**+8.9**	**65,483**	**0.0**	**6,804**	**0.0**	**45,797**	**+2.0**
14	Hebron Peatlands	3,750	615	+2.4	15,992	0.0	993	0.0	21,360	+0.5
Total		129,797	23,324	-0.2	463,815	-5.3	34,943	-7.3	648,117	+0.8

* Subwatersheds in bold show the greatest change in pollutant loads.

Table 3.2 Pollutant Contribution Index

#	Subwatershed ID	Area (acres)	Contribution Index*			
			Sediment	Total N	Total P	FC**
1	**Lower Nippersink**	12,426	75	111	69	**126**
2	Glacial Park/Tamarack	12,583	79	115	81	111
3	**Wonder Lake**	7,881	84	78	84	**119**
4	**Vander Karr Creek**	12,226	109	104	111	110
5	**Silver Creek**	12,005	80	97	72	**127**
6	Slough Creek	11,871	102	110	105	111
7	**Bailey Woods**	**7,281**	122	**121**	**131**	110
8	Nippersink Headwaters	6,594	77	117	84	111
9	**Zenda Headwaters (Wisconsin)**	**4,315**	**322**	**149**	**314**	116
10	North Nippersink	6,754	94	100	94	117
11	Lower Elizabeth Lake Drain	3,078	84	104	88	114
12	Elizabeth Lake	4,493	67	48	68	82
13	Upper North Branch Nippersink (Wisconsin)	24,540	104	75	103	37
14	Hebron Peatlands	3,750	91	119	98	114
Total		129,797				

* Contribution index = (Percent of total watershed load coming from subwatershed ÷ Percent of watershed area that subwatershed comprises) × 100. Index above 100 indicates subwatershed produces disproportionately large pollutant load. (This metric was adopted from Poplar Creek Watershed Action Plan, CMAP, 2006)
** FC = Fecal coliform; FCU = Fecal coliform Unit

3.3. Pollutant Load Reduction

3.3.1 Setting Pollutant Load Reductions Targets

Once a pollutant has been linked to a known impairment, management strategies are needed to reduce those loads to bring the impaired water bodies to compliance (i.e. to meet their designated uses). Procedures for estimating the desired load reductions range from simple to complex models, depending on the objectives of the management strategy. If planning level estimates are needed for purposes of selecting suitable BMP's or policy decisions, then simple approaches are appropriate. Complex approaches are needed when accurate estimates are needed for implementing strict pollution controls such as wastewater treatment plant upgrades.

For the purposes of this study, a simple procedure based on previous monitoring data or literature values from similar watersheds appears appropriate. Table 3.3 shows typical water quality statistics for total phosphorus and suspended sediment upstream of Wonder Lake. These values may be assumed to represent the concentration of the inflow into the lake. The mean suspended sediment concentrations are below the Illinois EPA guideline of 113 mg/L.

Phosphorus loads are the most critical for the lake because the mean concentrations are significantly above the water quality standard for Lakes (WQS) of 0.05 mg/L. To bring the lake into compliance, the phosphorus concentrations would need to be reduced by 68.5%. Since a significant portion of phosphorus loads is transported by sediment, reducing sediment loads by the same amount would be expected to reduce phosphorus loads significantly.

The target reduction will be achieved by a combination of BMP's and appropriate land use policies as discussed below. Even though other pollutants associated with rural or urban runoff were not modeled, most BMP's do remove multiple pollutants. Therefore, successful implementation of BMP's will result in reducing most other pollutants, with the exceptions of chlorides. The Nippersink watershed plan includes a monitoring plan and criteria for assessing the effectiveness of the BMP's in reducing pollutant loads.

Table 3.3 Water Quality Statistics Upstream of Wonder Lake

Statistic or Standard Water Quality Statistic	Total Phosphorus Concentrations mg/L	Suspended Sediment Concentrations. mg/L
Maximum	1.16	808
Minimum	0.02	1.2
50 Percentile of samples	0.1	63
Mean	0.159	89.3
Standard Deviation	0.177	75.6
Illinois Water Quality Standard (IWQS) or Guideline	0.05**	113*

Source: USGS, 2001 Study
mg/L =milligrams per Liter
* A guideline, not an IWQS
** IWQS for lakes.

3.3.2 Pollutant Load Reduction Strategies

Effective strategies of reducing pollutant load are based on the characteristics of the pollutants sources and the nature of the impairments. In the Nippersink watershed, the predominant sources of the pollutants are non-point sources that are primarily a result of agricultural practices. As the watershed is developed, management strategies for reducing pollutants must take into account the changing mix of pollutants. Post development pollutants could be contributed by both point and non-point sources that include a wider array of pollutants. Post-development pollutants of concern may no longer be just nutrients. They may consist of other pollutants typical of urbanized watersheds such as metals, PCBs, habitat alteration, temperature or pH.

The Nippersink watershed is a large watershed that is going to remain predominantly agricultural for years into the future. Based on the pollutant load analysis results, the most reasonable strategy should concentrate on:

- Agricultural BMP's to reduce nutrient loads from the mostly rural areas. In Table 3.1, nine watersheds remain relatively unchanged.
- A mixture of Agricultural and urban BMP's targeted at the rapidly developing subwatersheds or 'hot spots' such as Wonder Lake, Silver Lake, the Lower Elizabeth Drain Lake and the Lower Nippersink subwatersheds.
- BMP's that protect subwatersheds with the highest quality natural resources

The removal efficiencies of urban and BMP's such as detention basins, rain gardens, swales, and low impact design are widely documented. The American Society of Civil Engineers (ASCE) in cooperation with the EPA (http://www.bmpdatabase.org/) now maintains a database of field data on actual performance of various BMP's across the country. Removal efficiencies of BMP's in the field vary from 10 to 70 percent of pollutant loads depending on specific site and storm conditions. The GWLF model indicated that agricultural BMP's such as nutrient management and land conversion to forest were very effective in reducing pollutant loads. The BMP's selected for the subwatersheds in the Nippersink watershed are presented in the following sections.

3.4 BMP Selection

The EPA in cooperation with the NCRS and other governmental agencies has created two resource centers which describe variety of BMP's resources for addressing a range of pollutants in both agricultural and urban settings. Comprehensive menus of BMP's for addressing urban runoff are available at (http://cfpub.epa.gov/npdes/stormwater/menuofBMP's/index.cfm). These BMP's were intended to assist municipalities prepare effective programs for implementing the Stormwater Phase II was first released in October 2000.

BMP's targeted at reducing non-point pollution from agricultural practices are available at the Conservation Technology Information Center (CTIC): http://www.conservationinformation.org) for the USDA Natural Resources Conservation Service (NCRS) and THE EPA. Agricultural BMP's are particularly important because the Nippersink Creek watershed is still predominantly agricultural. Two categories of BMP's were considered for addressing pollutant loads in the Nippersink watersheds. Programmatic or BMP's are those that apply to the whole watershed. Site specific BMP's were developed to address pollutant sources at specific or localized areas.

A selection of programmatic BMP's recommended for the Nippersink watershed include:

- **Regulatory BMP:** Regulatory BMP's include ordinances, regulations, and enforcement procedures that are applicable throughout the watershed and which have a cumulative effect of preventing water quality degradation. Examples include NPDES Phase II pre- and post-construction pollution prevention regulations, zoning codes and regulations countywide stormwater regulations, soil-erosion and sediment control regulations and permitting, and disposal of hazardous wastes. Their effectiveness in reducing pollutant loads vary depending on the degree of enforcement. Regulation-driven pollution prevention controls can reduce pollution significantly (Lori S., Bear, 2007). For purposes of estimating pollutant reduction or removal efficiency of regulatory programs, conservative reduction rates of 2 to 5% have been assumed.

- Street sweeping: The effectiveness of street sweeping in removing pollutants varies greatly depending on frequency and the sophistication of the equipment. Modern vacuum dryer sweepers can reduce annual sediment loads by 55 to 88% and nutrients by 0 to 15% (Stormwater Managers Resource Center: http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/ParkingLotandStreetCleaning.htm)

- Practicing Low Impact Development (LID): LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Instead of conveying and managing / treating stormwater in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. This includes not only open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment / revitalization projects.

- Nutrient Management: Nutrient management is an effective measure for reducing nutrient loads from agriculture. Nutrient management involves managing the amount, source, placement, form and timing of the application of plant nutrients and soil amendment. Nutrient management also applies to farm animal operations. The McHenry County NRCS might already be conducting such a program in the watershed and its success might even be the reason why pollutant loads although elevated are not as high as in comparable watersheds in the country. It is recommended that the program be continued or expanded because of its effectiveness.

- Education and Outreach Programs: The primary goals of watershed education include increasing community awareness, preserving local water resources, and gradually changing resident behaviors to reduce the amount of pollutants from stormwater runoff. Education programs may focus outreach on a single behavior on a broad basis, or concentrate their efforts at the subwatershed level. The most effective watershed education programs focus on key pollutants or behaviors, carefully target their audiences, and survey residents to understand their attitudes before designing education campaigns. Examples include proper disposal of household chemicals, fertilizer applications, and road salt applications.

- Pet waste management: Pet waste management can be regarded as an example of and outreach program. Such a program however may be supplemented by local laws which enforcement actions. According to the 'The Practice of Watershed Protection, Art 17', the presence of pet waste in stormwater runoff has a number of implications for urban stream water quality with perhaps the greatest impact from fecal bacteria (for more information see. According to recent research, non-human waste represents a significant source of bacterial contamination in urban watersheds. Genetic studies by Alderiso *et al*. (1996) and Trial *et al*. (1993) both concluded that 95 percent of the fecal coliform bacteria found in urban stormwater was of non-human origin. Bacterial source tracking studies in a watershed in the Seattle, Washington area also found that nearly 20% of the bacteria isolates that could be matched with host animals were matched with dogs. Pet waste management is therefore could be an important component of reducing fecal coliform bacterial loads in urban runoff.

A selection of site-specific BMP's have recommended at specific locations in the watershed. Specific information about these BMP's such as location, costs and responsibilities about these BMP's is provided in Chapter 5.3 through 16.3. The BMP's are effective in reducing nutrients, fecal coliform and sediment loads. The BMP's include:

- Preserving open lands to promote infiltration
- Wetland conversion/restoration to encourage retention and infiltration
- Removal/abandonment of agricultural tile systems.
- Riparian Buffers: A riparian buffer is an area of trees and/or shrubs or native vegetation located adjacent to and up-gradient from water bodies and water courses. The location, layout, width, length and plant density are designed to accomplish a specific purpose and function. Riparian buffers enhance bank stability, provide (1) A source of detritus and woody debris for fish and other aquatic organisms, (2) Provide wildlife corridors, and (4) Reduce excess amounts of sediment, organic material, nutrients, and pesticides and other pollutants in surface runoff and reduce excess nutrients and other chemicals in shallow ground water flow. In the Nippersink Creek watershed, riparian buffers are useful in all streams, particularly those running through farmland and in steep channels banks such as those located in the Bailey Woods subwatershed.

- Retrofitting existing ponds, restoration of wetland systems
- Retrofitting outfalls, shoreline stabilization
- Stormwater Management/Wetland Systems: Stormwater management facilities that utilize a wet pond cell leading to a wetland cell have been reported to be very effective in removing pollutants from urban runoff (WERF, 2007). The wet pond cell is apparently very effective in pre-treating the incoming runoff; it also reduces its velocity and distributes it more evenly across the marsh.
- **Sand filters** are a relatively new technique for treating storm water, whereby the first flush of runoff is diverted into a self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes and returned back to the stream or channel. More detailed information such as typical layouts, performance and design of sand filters is available from the EPA at http://www.epa.gov/owm/mtb/sandfltr.pdf.
- **Filter Strips:** These are vegetated sections of land designed to accept runoff as overland sheet flow from upstream development. They may adopt any natural vegetated form, from grassy meadow to small forest. The dense vegetative cover facilitates pollutant removal. Filter strips cannot treat high velocity flows; therefore, they have generally been recommended for use in agriculture and low density development.
- A **Water Quality Inlet** is a three-stage underground retention system designed to remove heavy particulates and small amounts of petroleum products from storm water runoff. Also known as an **Oil/grit Separator** or an **Oil-water Separator**. As water flows through the three chambers, oils and grease separate either to the surface or to sediments and are skimmed off and held in the catch basin or storage tank. The storm water then passes on to the sanitary sewer, storm sewer.
- **Streambank Stabilization** controls erosion through management of water velocity and/or stream bank stability by natural and manmade controls to decrease bank erosion and sediment loading in waterways. Structural or vegetative means may be used separately or together.

Each of these BMP's may be applied individually or in combination to meet desired pollutant load reduction targets for each subwatershed as presented in each subwatershed report (Chapters 5 through 16). The sizes of the BMP's provide a general indication of the potential land available for implementing the BMP's. Priority watersheds for reducing fecal coliform bacteria loads are the Lower Nippersink and Silver Creek watersheds. The BMP's recommended for the remaining watersheds may also reduce fecal coliform bacteria loads but additional monitoring will provided better information about which watershed to target as the plan is implemented over the years. As previously discussed, the actual success of the BMP's will need to be monitored by sampling for both chemical constituents and biological indicators. A recommended sampling program is discussed in Chapter 19.