Pine Creek Watershed Implementation Plan
FINAL - October 2009

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Executive Summary
Pine Creek Watershed Implementation Plan

The goal of this plan is to determine how best to reduce the nonpoint source pollutant loads in the Pine Creek Watershed (Allegheny County, Pennsylvania). Pine Creek is a 22.8 mile long tributary to the Allegheny River. Its watershed is 67.3 square miles in area and contains approximately 128 stream miles. The watershed is located just north of the City of Pittsburgh and the land use varies from highly urban areas in the lower part of the watershed to typical suburban commercial and residential developments. The population within the watershed is estimated to be 91,000 persons. The estimated impervious cover in the watershed is 8.3%.

The Pennsylvania Department of Environmental Protection's *2008 Integrated Water Quality Monitoring and Assessment Report* identified several segments of streams within the watershed that are impaired for one or more designated uses. The report lists nutrients, pathogens, and siltation as the types of pollutants affecting the waterway. These pollutants are primarily from urban runoff and storm sewers, but other sources include land development, on site wastewater, small residential runoff, and unknown sources. Total Maximum Daily Loads have not been developed for any areas within the watershed.

An evaluation of nonpoint source pollution in the watershed was conducted using the geographic information system (GIS) based watershed assessment tool AVGWLF and methods contained in the Center for Watershed Protection (CWP) Manual: *Urban Stormwater Retrofit Practices.* These methods modeled the existing conditions and determined the effects of proposed improvement.

The model showed pollutant loading of total suspended solids, nitrogen, and phosphorus. A separate study evaluating the riparian zone and stream channel indicated areas of severe erosion and damage from excessive stormwater.

The analysis determined that five main approaches should be followed to reduce the impacts of urbanization.

1. The proper implementation of the Act 167 Stormwater Management Ordinance requirements adopted by the Pine Creek municipalities in 2008. These requirements will insure that all significant future development or redevelopment in the watershed be constructed using water quality best management practices (BMPs). The ordinance encourages flow volume reduction through the use of natural area conservation, stream buffers, enhanced swales, infiltration zones (rain gardens), and environmentally sensitive subdivisions.

2. The construction of approximately 19,000,000 cubic feet of additional water quality BMPs in the watershed to reduce pollutant loading from developed areas. It is recommended that a portion of these water quality volume (WQv) BMPs be developed by retrofitting existing stormwater dry ponds into wet ponds.

3. The stabilization of the stream banks to reduce erosion. It was determined that approximately 5.3 more miles of stream bank should be stabilized to control the total suspended solids (TSS) loads to that of the pre-developed condition.

4. The use of "Green Streets" concepts in the lower highly urbanized portions of the watershed located in Etna Borough. This concept uses methods such as street side rain gardens and the separation of combined sewers to reduce urban runoff and sewer overflows into the waterway.

5. The protection of steep slopes and natural areas in the watershed. It is recommended that municipalities adopt steep slope protection ordinances and encourage the use of conservation easements to protect natural areas within the watershed.

It is estimated that the construction costs to add the additional WQv BMPs, stabilize the stream banks, and install the Green Streets concepts in Etna (numbers 2, 3, and 4 described above) will range from 11 to 12 million dollars. The costs of the other recommendations are variable because the number and types of projects cannot be determined at this time.

This Watershed Implementation Plan should be viewed in the context of a much larger Act 167 Stormwater Management Study that is underway in the watershed. The Act 167 study will create a detailed GIS based watershed model that will evaluate multiple flood control and water quality improvement scenarios. It is anticipated that the Act 167 study will further the detail provided in this plan.

Also, it is hoped that the Act 167 study will lead to a more comprehensive watershed based management of stormwater BMPs and flood control projects. Currently, there is no single authority that has the responsibility to manage the existing or proposed stormwater BMPs in the watershed. These facilities are owned by either private owners, one of fourteen different municipalities, Allegheny County, or the Commonwealth of Pennsylvania.

The Pine Creek Watershed Coalition, a group of stakeholders committed to improving the health of the Pine Creek watershed, has been identified to educate the citizens about the plan, set priorities, review projects, develop milestones, and seek funding for projects. The Coalition manages a corps of volunteer water quality monitors who can provide data to evaluate the effectiveness of remediation efforts and has developed its own website to keep the public informed of projects in the watershed (www.pinecreekwpa.org). Additionally, the North Hills Council of Governments will have primary responsibility for prioritizing, evaluating, and managing projects related to stormwater management ponds, ordinance revisions, and flood plain restoration and protection as it continues its leadership with the implementation of the Act 167 Plan.

Chapter 1: Watershed Background

A. Purpose of a Watershed Implementation Plan

The ultimate goal of a Watershed Implementation Plan (Plan) is to reduce nonpoint source pollution by identifying appropriate Best Management Practices (BMPs) for a watershed and creating a mechanism and schedule for implementation. While these Plans are typically used for the development of Total Maximum Loads (TMDLs), the Plan for the Pine Creek watershed seeks to address pollutant reduction on impaired streams before the development of TMDLs.

The EPA has developed a list of elements that must appear in a Plan. These include:

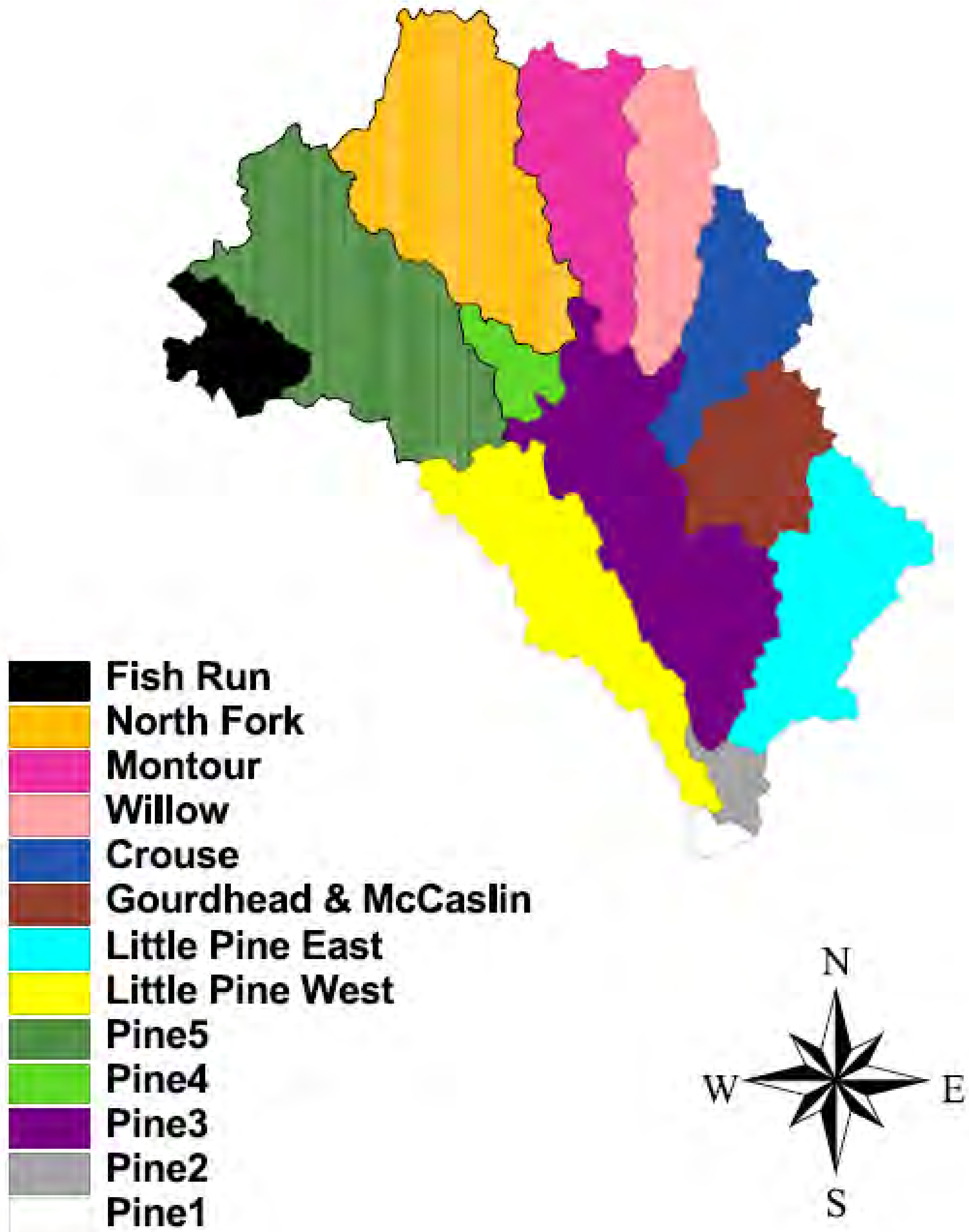
- Identification of pollution sources
- Pollutant load reductions required to meet TMDLs
- Management measures required to achieve load reductions
- Technical and financial assistance needed to implement BMPs
- Public information and participation
- Implementation schedule and evaluation
- Water quality monitoring and evaluation
- Remedial actions

This Plan was prepared by Janette M. Novak of the Pennsylvania Environmental Council with engineering services provided by Art Gazdik, P.E (artgazdik@gmail.com). The views expressed herein are those of the authors and do not necessarily reflect the views of EPA, DEP, or any of its subagencies.

B. Study Area

1. Physical Description

Pine Creek is a 22.8 mile long stream in northern Allegheny County that begins in Pine Township and drains into the Allegheny River in the Borough of Etna. Its watershed is 67.3 square miles (43,072 acres) and contains approximately 128 stream miles. For the purposes of this study, the watershed has been subdivided into several subwatersheds, see Map 1.



Map 1: Pine Creek Watershed and Subwatersheds

The watershed is comprised of hilly terrain. It has moderate to low relief and a dendritic stream pattern.

Soils in the watershed vary in thickness, composition, and porosity. Generally, most of the soil is well drained on the uplands. However, the floodplains are typically poorly drained. Specific information about soils can be found in the *Soil Survey of Allegheny County, Pennsylvania*, published in 1981 by the U.S. Department of Agriculture Soil Conservation Service and in the 1972 publication *Our Land: A Study of the Pine Creek Watershed*, published by the North Area Environmental Council.

Allegheny County is highly susceptible to landslides. A combination of a humid temperate climate, locally steep and rugged topography, weak rock strata, springs, and a great diversity in the weathering and erosion characteristics of near surface sedimentary rocks makes this area one of the most slide-prone areas in the state. In addition, landslides can be triggered by:

- Addition of fill, which increases the stress on underlying materials,
- Removal of trees,
- Changes in quantity or the direction of water flow,
- Surface and subsurface excavations (including coal removal), and
- 'Red Beds'- bedrock in hillsides composed of claystones and shales that are 40-60 feet deep. This bedrock weathers easily, especially when wet, and causes unstable slopes.

Stabilization and repair can cost thousands to millions of dollars.

2. Land Cover

The land area of the Pine Creek Watershed covers parts of 14 municipalities. See Table1-1.

Table 1-1: Pine Creek Municipalities

Municipality	Total Area (sq. mi)	Watershed Area (sq. mi)	Watershed Area as % of Municipality	Watershed Area as % of Watershed
Bradford Woods	0.93	0.54	58.49	0.81
Etna	0.81	0.67	82.59	1.00
Fox Chapel	8.50	0.30	3.58	0.45
Franklin Park	13.55	3.86	28.46	5.74
Hampton	16.05	14.99	93.38	22.29
Indiana	17.00	3.25	19.11	4.83
Marshall	14.79	0.96	6.48	1.43
McCandless	16.40	12.99	79.18	19.32
O'Hara	7.01	1.40	19.93	2.08
Pine	17.12	12.30	71.85	18.30
Richland	14.68	6.66	45.33	9.90
Ross	14.50	1.44	9.94	2.14
Shaler	10.74	7.87	73.24	11.70
Sharpsburg	0.75	0.02	2.13	0.02

The watershed's population is estimated to be 91,000 persons. The communities near the mid to lower section of Pine Creek as well as those near the West Branch of Little Pine Creek are the most developed in the watershed. While the headwaters section of the basin is the least developed, there is a significant transformation underway from rural communities and farmlands to suburban communities and commercial districts. This is illustrated in Tables 1-2 and 1-3.

Table 1-2: Change in Municipal Population

Municipality	1990 Population	2000 Population	% Change
Bradford Woods	1,329	1,149	-14
Etna	4,200	3,924	-7
Fox Chapel	5,319	5,436	2
Franklin Park	10,109	11,364	12
Hampton	15,568	17,526	13
Indiana	6,024	6,809	13
Marshall	4,010	5,996	49
McCandless	28,781	29,022	0.8
O'Hara	9,096	8,856	-3
Pine	4,048	7,683	90
Richland	8,600	9,231	7
Ross	33,482	32,551	-3
Shaler	30,533	29,757	-3
Sharpsburg	3,781	3,594	-5
Source: PA State Data Center, Penn State Harrisburg. http://pasdc.hbg.psu.edu			

Table1-3 illustrates development through housing units (single or multiple units, mobile homes, etc.).

Table 1-3 Change in Municipal Housing Units

Municipality	1990 Units	2000 Units	% Change
Bradford Woods	476	478	0.4
Etna	1,867	1,934	4
Fox Chapel	1,887	1,942	3
Franklin Park	3,420	3,973	16
Hampton	5,526	6,627	20
Indiana	2,208	2,457	11
Marshall	1,382	2,018	46
McCandless	10,933	11,697	7

O'Hara	3,377	3,381	0.1
Pine	1,514	2,500	65
Richland	3,201	3,508	10
Ross	14,124	14,422	2
Shaler	11,830	12,334	4
Sharpsburg	1,864	1,911	2
Source: PA State Data Center, Penn State Harrisburg. http://pasdc.hbg.psu.edu			

While six of the 14 communities saw declines in their population during a ten-year period, municipal housing units increased in all municipalities.

Most of the commercial and industrial development in the watershed has been along State Route 8 in Shaler and Etna and along the McKnight Road and Perry Highway (U.S. Route 19) corridor in McCandless, where strip malls are common. More recent commercial development has and continues to occur near the Wexford interchange of Interstate 79. However, the 2002 Route 8 Economic Development Plan produced by the Route 8 Partnership seeks to strengthen the regional marketplace of the Route 8 Corridor to attract and diversify development. This is particularly significant to the lower portion of Pine Creek, which is adjacent to Route 8.

There are significant undeveloped or green areas (forests and grasslands) throughout the watershed. Some of this can be explained by steep forested slopes, which are unable to be developed, as well as managed recreation areas, such as North Park.

The *Allegheny County Natural Heritage Inventory*, published by the Western Pennsylvania Conservancy in 1994, listed several Pine Creek sites as significant natural heritage areas for the county. These sites either provide habitat for species of special concern or serve as an educational and scientific area with the potential for natural areas management. Sites listed are:

- Allegheny River
- Crouse Run
- Hemlock Grove, North Park
- Willow Run Slopes, North Park
- North Park
- Beechwood Farms Nature Reserve
- Cold Valley

North Park, at 3,010 acres, is the largest of the County Parks. It is mostly used for recreation and very little remains in its natural state. The U.S. Army Corps of Engineers is working on an aquatic ecosystem restoration project of North Park Lake, which has lost some of its depth due to growing silt deposits. Approximately 400,000 cubic yards of sediment will be dredged and removed from the Lake and will be deposited to an offsite location. Work began in 2009 and will continue for three years.

Chapter 2: Water Quality Characteristics

A. Water Quality Standards and Designated Uses[1]

All surface waters in Pennsylvania have been assigned statewide water uses, and should be able to support these uses: aquatic life, water supply, and recreation. In addition to meeting the standards for each of these statewide uses, some water bodies meet standards that make them eligible for other uses, or designations. Pine Creek is designated as a cold water fishery (CWF) from its source to North Park Lake Dam and a Trout Stocked Fishery (TSF) from the North Park Lake Dam to its mouth.

Water quality standards set the general and specific goals for the quality of our surface waters. They are based upon the water uses to be protected, the surface water conditions that need to be maintained or attained to support those uses, and an antidegradation policy which protects and maintains existing uses. Water quality standards are implemented by regulatory requirements (e.g. effluent treatment requirements or limitations) and Best Management Practices (BMPs). Best Management Practices are defined as activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce pollution to surface waters.

Therefore, to control and regulate the amount and types of pollution entering our waterways and to help achieve designated uses and prevent water quality degradation, point sources of pollution must have proper permits to discharge wastes into the nation's waters. The National Pollutant Discharge Elimination System (NPDES) is a permitting system that targets point source dischargers, such as industrial facilities and wastewater treatment plants. Permitted facilities must meet stringent effluent limits and are responsible for monitoring and reporting to the Pennsylvania Department of Environmental Protection (DEP).

While NPDES permits target only point source pollution, another approach to targeting all pollution sources, especially nonpoint, is through the use of Total Maximum Daily Loads (TMDLs). The Clean Water Act calls for the development of TMDLs for all waterways that do not meet water quality standards.

Assessed waterways that do not meet their designated use, must be listed by the state every two years, in accordance with Section 303(d) of the Clean Water Act, which is the list of impaired streams and rivers. The Clean Water Act also requires a water quality assessment report (305(b)) on all impaired waters every two years along with the 303(d) list. DEP has combined these reports into an *Integrated Water Quality Monitoring and Assessment Report*. "This report provides summaries of various water quality management programs including water quality standards, point source control, and nonpoint source control. It also includes descriptions of programs to protect lakes, wetlands, and groundwater quality."[2] Furthermore, the 305(b) report describes the extent to which waterways are supporting their designated uses. For example, if in

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[1] 2008 *Integrated Water Quality Monitoring and Assessment Report*, DEP
[2] PA DEP www.dep.state.pa.us

a particular waterway all designated uses are achieved, the waterway is listed as “fully supporting.”

Waterways listed within Section 303(d) are prioritized for TMDL development based on the severity of impairment. The DEP is incorporating them on a watershed basis where local watershed groups actually implement the TMDL Plan and do testing with DEP's assistance.

According to the DEP, the TMDLs set an upper limit on the pollutant loads that can enter a water body, so that the water will meet water quality standards. The Clean Water Act requires states to list all waters that do not meet their water quality standards, even after required pollution controls are put into place. For streams on this list, the state calculates how much of a substance can be put into the stream without violating the standard and then distributes that quantity among all sources of the pollution on that water body. A TMDL plan includes waste load allocations for point sources, load allocations for nonpoint sources, and a margin of safety. States must submit TMDLs to the Environmental Protection Agency (EPA).

The *2008 Integrated Water Quality Monitoring and Assessment Report* notes that segments of the following streams, and their unnamed tributaries, in the Pine Creek Watershed meet the standards for at least one use (that of aquatic life), but that the attainment status of remaining designations is unknown because of insufficient data:

- Gourdhead Run
- Montour Run
- Little Pine Creek (East and West Branches)
- North Fork of Pine Creek
- Pine Creek
- Rinaman Run
- Willow Run

Waters with stream segments that are impaired for one or more designated uses and that require a TMDL appear in Table 2-1.

Table 2-1: Impaired for One or More Designated Uses by Any Pollutant and Requiring a TMDL

Stream	Designation/Source	303(d) list date	TMDL target date	Total stream miles impacted	Pollution Characterization
Crouse Run (plus unnamed tributaries)	Aquatic Life Urban Runoff/ Storm Sewers	2002	2015	7.74	Nutrients
	Recreational Source Unknown	2008	2021	7.74	Pathogens

Fish Run (plus unnamed tributaries)	Aquatic Life Land Development Urban Runoff/ Storm Sewers	2002	2017	4.43	Nutrients Siltation
	Recreation Source Unknown	2008	2021	4.43	Pathogen
Gourdhead Run (plus unnamed tributaries)	Aquatic Life Urban Runoff/Storm Sewers	2002	2015	5.5	Nutrients
	Recreation Source Unknown	2008	2021	5.5	Pathogen
West Little Pine Creek (plus unnamed tributaries)	Aquatic Life Urban Runoff/ Storm Sewers	2002	2015	1.07	Nutrients
	Recreational Source Unknown	2008	2021	22.5	Pathogens
McCaslin Run	Aquatic Life Urban Runoff/ Storm Sewers	2002	2015	1.95	Nutrients
	Recreational Source Unknown	2008	2021	1.95	Pathogens
Montour Run	Recreational Source Unknown	2008	2021	17.16	Pathogens
North Fork Pine (plus unnamed tributaries)	Recreation Source Unknown	2008	2021	19.88	Pathogens

Pine Creek (plus unnamed tributaries)	Aquatic Life Land Development Small Residential Runoff On Site Wastewater Urban Runoff/Storm Sewers	2002	2015	40.63	Siltation Nutrients Low Dissolved Oxygen Organic Enrichment
	Recreational Source Unknown	2008	2021	40.63	Pathogens
Rinaman Run (plus unnamed tributaries)	Recreation Source Unknown	2008	2021	6.1	Pathogens
Wexford Run (plus unnamed tributaries)	Aquatic Life Urban Runoff/Storm Sewers Land Development	2002	2017	3.62	Siltation Nutrients
	Recreation Source Unknown	2008	2021	3.62	Pathogens

B. Recent and Ongoing Water Quality Monitoring

1. Chemical and Biological

In 2005, the Pennsylvania Environmental Council, in cooperation with a coalition of organizations, municipalities, and volunteers, prepared the *Pine Creek: Watershed Assessment, Protection, and Restoration Plan* (Assessment). The Assessment provided baseline data on water quality throughout the watershed and included a comprehensive database of its municipalities' current land use policies and practices. The Assessment's water quality data were gathered by volunteers at 16 locations throughout the watershed. Volunteers were trained and operated under the auspices of the Environmental Alliance for Senior Involvement (EASI)/ Pennsylvania Senior Environmental Corps (PaSEC). The findings from the Assessment are summarized below:

Table 2-2: Water Quality Criteria and Assessment Summary		
Parameter	**25 Pennsylvania Code Section 93.7 Specific Water Quality Criteria**	**Summary of Results from 2005 Pine Creek Assessment**
Water Temperature	Varies by month. Maximum temp. depends on critical use (Cold Water Fishery, Warm Water Fishery, Trout Stocked Fishery)	Seven sites exceeded mean water temperatures during summer months
pH	From 6.0 to 9.0 inclusive	Four sites met recommended criteria. Ten sites had high (alkaline) maximum or season mean readings and two sites had low (acid) minimum or season average readings.
Dissolved Oxygen	Depends on critical use and time of year. Minimum range from 4.0 mg/L to 6.0 mg/L	All stream sampling locations had dissolved oxygen levels meeting the criteria for its designated use.
Conductivity	No criteria provided (The Pa Senior Environmental Corps Water Quality Training Manual report that streams supporting good mixed fisheries have a range of 150 and 500 µmhos/cm)	Consistently exceeded criteria at almost all monitoring sites.
N, Nitrate + Nitrite	Maximum 10 mg/L for potable water supplies	Data results inconclusive.
Phosphate	No criteria provided (The Pa Senior Environmental Corps Water Quality Training Manual reports a maximum of 0.03 mg/L in healthy streams)	Consistently exceeded the criteria at almost all of the monitoring sites.
Sulfate	Maximum 250 mg/L for potable water supplies	Consistently exceeded criteria at almost all monitoring sites.
Alkalinity	Minimum 20 mg/L as $CaCO_3$ except where natural conditions are less	All locations met the criteria.
Water Quality Score (Benthic Survey)	No Criteria provided. (The Pa Senior Environmental Corps Water Quality Training Manual reports that scores	Eight sites received a fair score. One received a good score (in North Park). One received a poor score

	greater than 40 indicate good water quality, between 20 and 40 are fair water quality, and less than 20 are poor water quality)	(Headwaters of Pine Creek).

The entire Assessment, which includes summaries of water quality data by site and by season, is available at www.pinecreekwpa.org.

2. Bacteriological[3]

In 2006-2007, an intensive year long pilot program was conducted in the Pine Creek Watershed to determine its support of recreational use. The project was completed in conjunction with EPA Region 3, 3 Rivers Wet Weather, and the Pine Creek Watershed Coalition. Samples were collected weekly by volunteers from November 2006 through October 2007 at 25 locations throughout the watershed. Samples were analyzed at the Allegheny County Sanitary Authority laboratory to determine fecal coliform and E.coli densities, which were used to determine recreational use attainment.

Twenty-five sampling sites were dispersed throughout the Pine Creek watershed to ensure that an accurate depiction of the water quality would be represented. Stations were located in areas impacted by combined sewer overflows, sanitary sewer overflows, sewage treatment plant discharges, high development areas, and recreational parks. The only location to meet recreational use attainment was located on Willow Run. The remaining sites were determined to be impaired. The impaired sites had more than two months during the bathing season in which the geometric mean exceeded the current standard of 200cfu/100ml.

The final phase of the pilot program will be to submit the results to an independent contractor to produce a model suitable for the evaluation of the dynamics of bacteriological fate in flowing waters, a sampling plan and associated quality assurance documents, and a pilot sampling effort to generate data to test the efficacy of the model. If the approach proves to be effective, it will be applied statewide in an effort to enhance the effectiveness of this aspect of use attainment assessment.

3. Physical

Nearing completion is a two year Riparian and Stream Channel Assessment that examines and rates the stream channels throughout the watershed. In this effort, spearheaded by the North Area Environmental Council, teams of volunteers walked significant portions of Pine Creek and its tributaries and completed a visual assessment data sheet that documented the condition of the streams and banks. At stream waypoints, latitude and longitude were registered by GPS and a description of the land uses on both sides immediately adjacent to the stream was noted. Pipe

[3] Information provided by Angela Bransteitter, Water Pollution Biologist, DEP – February 2008

outlets, debris, erosion, wetland or invasive plants and tributary entries were documented and an overall visual assessment score was established.

The visual assessment scores rate ten parameters and averages the individual scores for a total average. These parameters include:

- the channel condition
- riparian zone
- bank stability
- water appearance
- nutrient enrichment
- fish barriers
- in-stream fish cover
- embeddedness
- invertebrate habitat
- canopy cover.

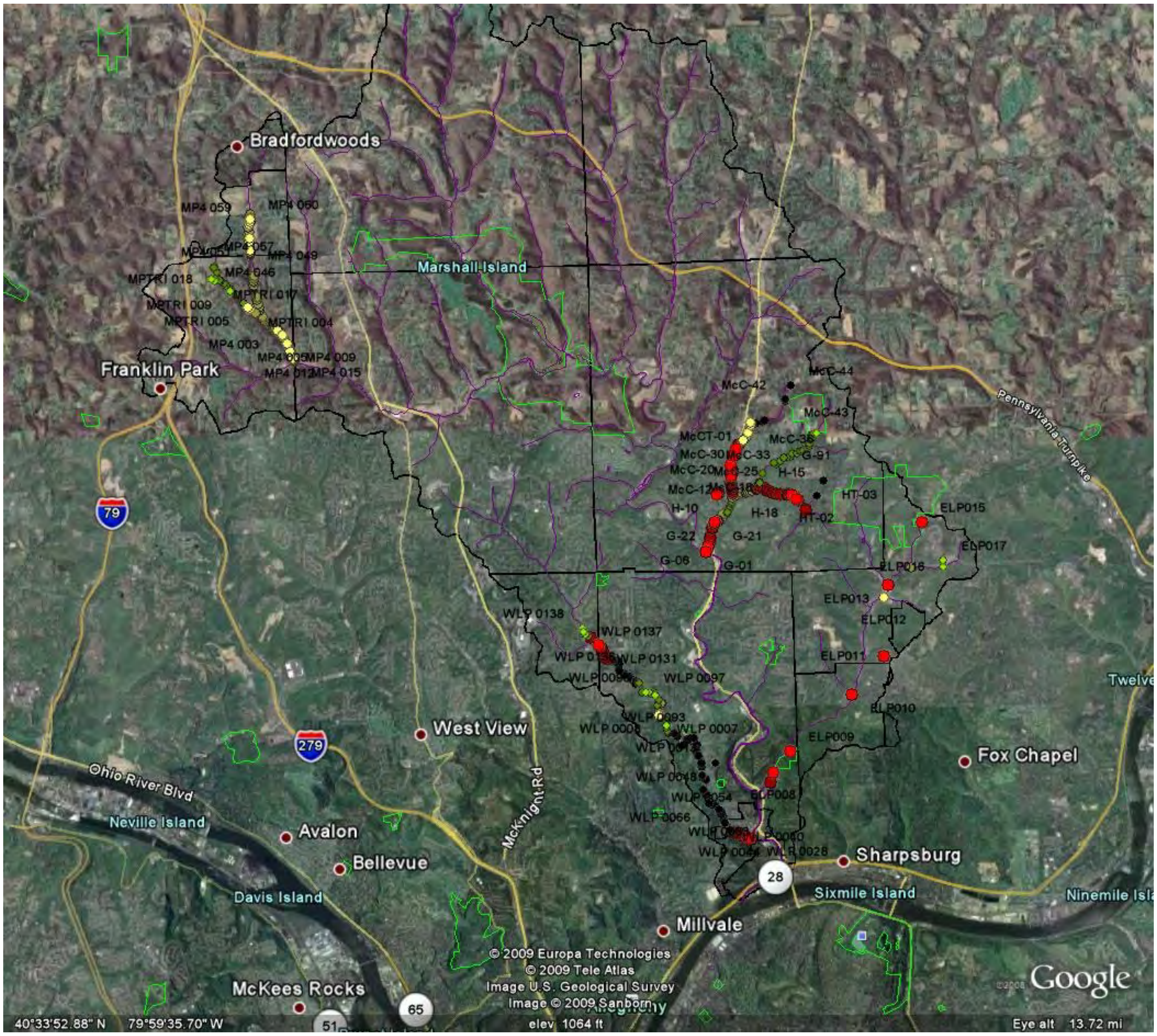
The average score is then rated from poor to excellent. In addition, photos were taken at critical points and to document general stream condition.

Currently, data have been collected for Gourdhead Run and its tributaries Hart's Run and McCaslin Run, East Little Pine Creek, West Little Pine Creek, Crouse Run, and parts of the upper main stem of Pine Creek. Results show the following assessment rating:

Table 2-3: Summary of Average Ratings for Riparian and Stream Channel Assessment

Stream	**Average Rating**
Gourdhead Run	Poor (mouth) to Good (headwaters)
Hart's Run	Fair
McCaslin run	Fair to Poor
East Little Pine	Poor; headwaters good
West Little Pine	Variable; high number of Poor segments
Crouse Run	Fair to Poor
Pine Creek Main Stem (upper)	Fair to Good

Map 2-1 highlights the data on a map of the Pine Creek Watershed. Red indicates a poor rating, yellow indicates a fair rating, and green indicates a good assessment rating.



Map 2-1: Documented Problems in Stream Channel Assessment

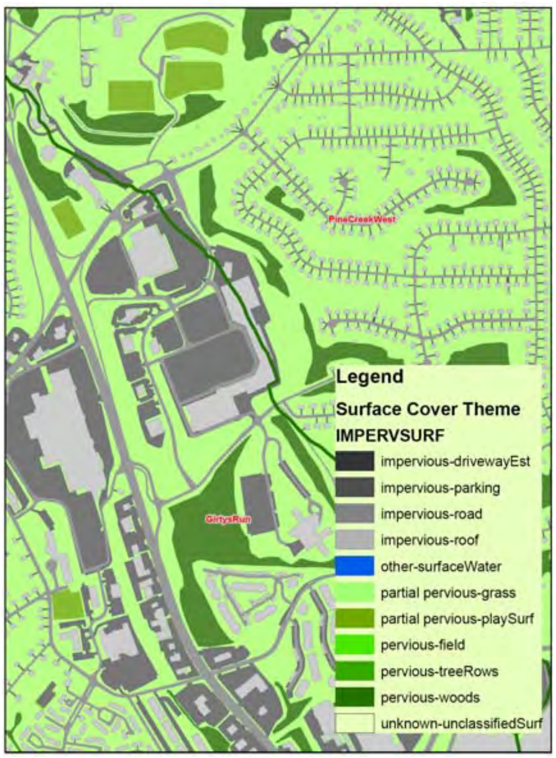
Complete documentation of the Riparian and Channel Assessment is being developed by the North Area Environmental Council and will be available in late 2009. This document should be considered a companion to this Plan as it will prioritize sites for remediation and restoration. Ultimately, this information will define projects that can reduce nonpoint source pollution and improve water quality by restoring floodplains, restoring and revegetating eroded stream banks, and possibly altering flows through natural stream channel design.

C. Pollution Sources

The *Integrated Water Quality Monitoring Report* indicates that urban runoff and storm sewers are the predominant pollution source in the watershed. In addition to pollutants like excess nutrients and sediment, this runoff can include pesticides, lawn fertilizers, bacteria, metals, road salts, pet droppings, oil, and other chemicals and debris deposited or littered in urban areas. Also, as areas are urbanized, the natural watershed is changed. Wetlands are often filled and natural streams are redirected by man-made channels. This takes away nature's ability to filter out contaminants before they end up in larger bodies of water. Therefore, as watersheds become more urbanized, nonpoint source pollution increases.

A fundamental measurement of the urbanization of a watershed is the amount of watershed area that has been covered by impervious cover. Impervious cover is defined as a surface cover placed upon the land that does not allow water to pass through it to the existing soil. Impervious cover includes the roof area and pavement in a watershed.

An estimate of the impervious cover for the Pine Creek Watershed was determined in 2006 during the Act 167 Stormwater Management Update. The direct measurement of impervious cover GIS coverage was determined by the company Land Based Systems (LBS), a consultant located in Pittsburgh. The existing Allegheny County GIS data were used and updated by LBS using the 2006 USGS orthophotographs to determine impervious cover in the study area.



The Allegheny County GIS Database provided the following information needed to develop the impervious cover GIS layer:

- Building Foot Prints (2004)
- Road Pavement Edges (2004)
- Parking Lots (+/-1990)

LBS updated the older parking lot database by digitizing the boundaries of new parking areas from the 2006 USGS orthophotography. LBS also estimated (simulated) the area of driveway pavement in the watersheds by assuming that each home has a 10' wide driveway from the edge of the pavement to the front of the structure.

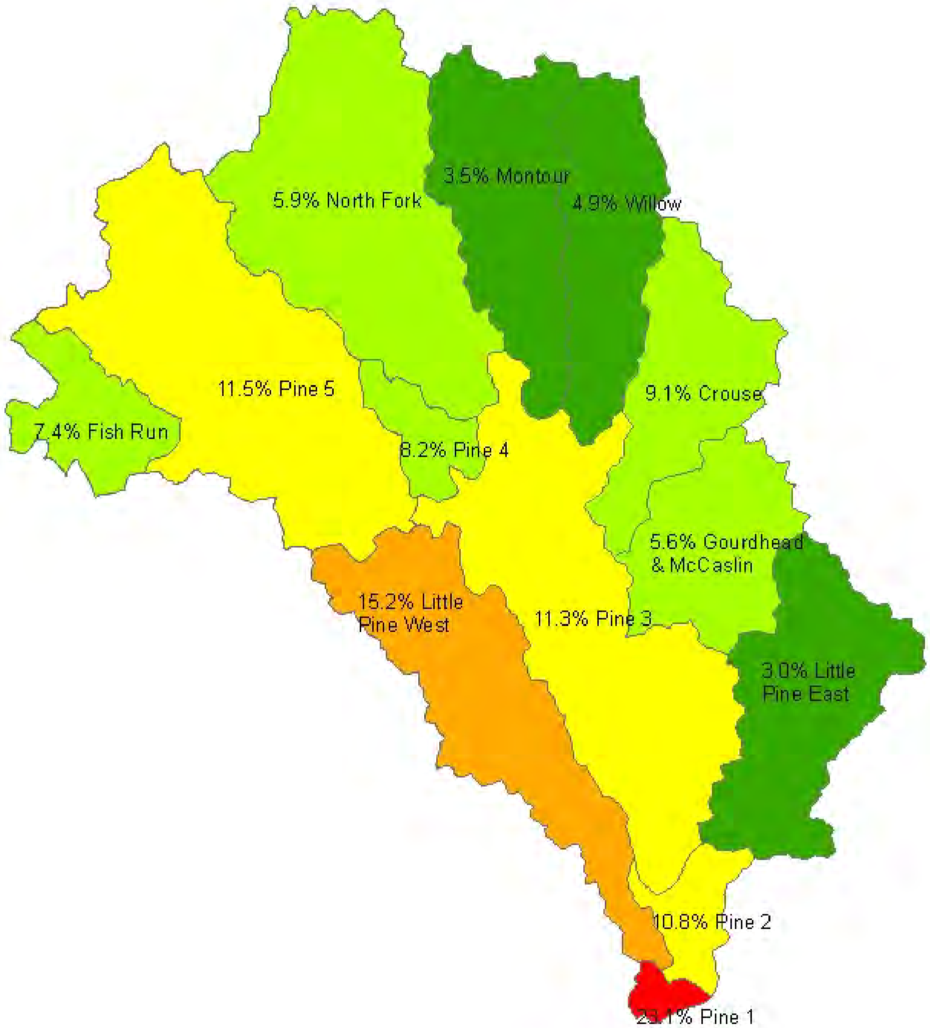
Figure 2-1: Sample of Impervious Cover Layer

A summary of the impervious cover for the Pine Creek Watershed is provided below and highlighted in Map 2-2 where the highest percentages of impervious surfaces are highlighted in red and the lowest percentages highlighted in dark green.

Table 2-4: Impervious Cover in the Pine Creek Watershed		
Sub Basin Name	**Sub Basin Area (sq. mile)**	**Impervious Cover (%)**
Pine 1	0.429	23.1%
Pine 2	1.342	10.8%
Pine 3	10.263	11.3%
Pine 4	1.304	8.2%
Pine 5	10.770	11.5%
Little Pine West	6.824	15.2%
Little Pine East	5.720	3.0%
Gourdhead & McCaslin	4.054	5.6%
Crouse	4.350	9.1%
Willow	4.427	4.9%
Montour	5.352	3.5%
North Fork	10.012	5.9%
Fish Run	2.383	7.4%
Entire Pine Creek Watershed	67.229	8.3%

Research by Schueler and the Center for Watershed Protection[4] has shown a strong relationship between the percentage of impervious cover in a watershed and the impairment of the watershed. Increases in impervious cover lead to increased flooding, increased channel erosion, increased sedimentation and damage to the ecosystem in the receiving stream. Schueler's studies have shown that streams are generally impacted when impervious cover exceeds ten (10%) percent. Note that the overall impervious cover percentage for Pine Creek is 8.3% and that several of the sub basins exceed the 10% value.

[4] Schueler, T.R., 1994. The Importance of Imperviousness. *Watershed Protection Techniques*, 1(3): 100-111.



Map 2-2 Percent Impervious Cover by Watershed

In order to control the effects of impervious cover on the watershed, BMPs such as stormwater management dry ponds have been mandated since the early 1980s. Dry ponds are designed to drain completely within 24 hours of a rain event. Stormwater management ponds must be installed by developers to insure that post development runoff rates do not exceed the predevelopment runoff rates from the site. In October 2008, the Act 167 Stormwater Management Plan for Pine Creek and three neighboring watersheds was revised to provide additional water quality, infiltration, and extended detention requirements. Details of these new revisions are provided later in this report and at www.ross.pa.us.

The *Integrated Water Quality Monitoring Report* also lists pathogens as a significant pollutant in the watershed that is attributed to an unknown source. Potential sources of these pathogens may be discharges from waste water treatment systems, failing home septic tanks, agricultural and stormwater runoff, and animal waste.

Chapter 3: Modeling Nonpoint Source Pollution Using AVGWLF and RUNQUAL

A. AVGWLF Model Description[5]

The extent and magnitude of nonpoint source pollution can be determined through long term surface water monitoring or through computer based simulation modeling. Surface water monitoring can be time and cost prohibitive, so computer simulation modeling is being used more frequently. Watershed simulation models can evaluate both the sources and controls of sediment and nutrient loading to surface waters. Simulation modeling is not without its downside. These models can be difficult because of the large geographic and temporal scales, as well as the large amount of data that are compiled, integrated, and interpreted. However, the use of Geographic Information System (GIS) technology has provided a way to manage these data issues.

Penn State University and the PA Department of Environmental Protection (DEP) have been working on various GIS-based watershed assessment tools. One such tool facilitates the use of the Generalized Watershed Loading Function (GWLF) model developed by Haith and Shoemaker (1987) via a GIS software (ESRI's ArcView 3.2) interface. This tool, called AVGWLF, has been selected by DEP to help support its ongoing TMDL projects within Pennsylvania. According to the AVGWLF website

"The general approach in such projects is to:

- derive input data for GWLF for use in an "impaired" watershed,
- simulate nutrient and sediment loads within the impaired watershed,
- compare simulated loads within the impaired watershed against loads simulated for a nearby "reference" watershed that exhibits similar landscape, development and agricultural patterns, but which also has been deemed to be unimpaired, and
- identify and evaluate pollution mitigation strategies that could be applied in the impaired watershed to achieve pollutant loads similar to those calculated for the reference watershed. The primary bases of comparison between impaired and reference watersheds are the average annual nutrient and sediment loads estimated for each.

The GWLF model provides the ability to simulate runoff, sediment, and nutrient (Nitrogen and Phosphorus) loadings from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values.

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[5] www.avgwlf.psu.edu

GWLF allows multiple land use/cover scenarios, but each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, rather it aggregates the loads from each area into a watershed total. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily temperature and precipitation inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values (where K = erosion; LS = length slope factor, C = vegetative cover factor, P = conservation practices) for each land cover/soil type combination. A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are then applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each source area. Point source discharges can also contribute to dissolved losses and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing area. Evapo-transpiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

In addition to the original model algorithms described above, a new streambank erosion routine was also implemented as part of AVGWLF. This routine is based on an approach often used in the field of geomorphology in which monthly streambank erosion is estimated by first calculating a watershed-specific estimated lateral erosion rate (LER) using the equation of the form

LER = aq0.6

Where a = an empirically-derived constant related to the mass of soil eroded from the streambank depending upon various watershed conditions, and
q = monthly stream flow in cubic meters per second.

After a value for ***LER*** has been computed, the total sediment load generated via streambank erosion is then calculated by multiplying the above erosion rate by the total length of streams in the watershed (in meters), the average streambank height (in meters), and the average soil bulk density (in kg/m3).

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated."

As described previously, the use of GIS software for deriving input data for watershed simulation models such as GWLF is becoming fairly standard practice due to the inherent advantages of using GIS for manipulating spatial data. In this case, a customized interface developed by Penn State for the ArcView GIS package is used to parameterize input data for the GWLF model.[6] In utilizing this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season; and the months during which manure is spread on agricultural land). This information is subsequently used to automatically derive values for required model input parameters which are then written to the TRANSPORT.DAT and NUTRIENT.DAT input files needed to execute the GWLF model. Also accessed through the interface is a statewide weather database that contains 25 years of temperature and precipitation data for 78 weather stations around Pennsylvania. This database is used to create the necessary WEATHER.DAT input file for a given watershed simulation.

B. RUNQUAL Model

The enhanced version of the GWLF model provided within AVGWLF can be used to simulate flows and loads within watersheds containing a variety of land use categories, including two types of urbanized or developed land (low-density development and high-density development). However, in very intensively developed watersheds, it may be more appropriate to use a model that more specifically considers hydrologic and pollutant transport processes in such areas. Consequently, in this latest version of AVGWLF, an additional modeling tool has been included to address this situation. This new tool is based on the RUNQUAL model developed by Haith (1993) at Cornell University. (Haith was also the developer of the GWLF model upon which the "Standard" watershed modeling approach used in AVGWLF is based). The model input structure used by RUNQUAL is very similar to that of GWLF, which greatly facilitated its implementation within AVGWLF. The software, software user guides, and other supporting documents are available on the AVGWLF website (www.avgwlf.psu.edu/).

[6] Evans, B.M., D.W. Lehining, K.J. corradini, G.W. Peterson, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day, 2002 A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. *Journal of Spatial Hydrology*, Vol. 2, (www.spatialhydrology.com).

The RUNQUAL model provides a continuous daily simulation of surface runoff and contaminant loads from developed land within a given watershed. In contrast to what is done in GWLF, flows and loads are calculated from both the pervious and impervious fractions associated with each land use/cover category used. The contaminated runoff may also be routed through various urban BMPs in order to simulate reductions that may occur prior to being discharged at the watershed outlet.

The runoff routines in RUNQUAL are adapted from the urban runoff component of the GWLF model.[7] Runoff volumes are calculated from procedures given in the U.S. Soil Conservation Service's Technical Release 55 (U.S. Soil Conservation Service, 1986). Contaminant loads are based on exponential accumulation and washoff functions similar to those used in the SWMM (Huber and Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977) models. The pervious and impervious fractions of each land use type are modeled separately, and runoff and contaminant loads from the various surfaces are calculated daily and aggregated monthly in the model output. Within RUNQUAL, it is assumed that the area being simulated is small enough so that travel times are less than one day.

RUNQUAL allows the user to consider the potential effects of BMPs on contaminated runoff. There are three basic types of BMPs than can be modeled -infiltration retention facilities, vegetated filter strips, and detention basins.

1) Infiltration facilities are trenches, basins and/or porous areas designed to allow specific volumes of runoff water to drain to underlying groundwater rather than directly to streams via overland flow.
2) Filter (or buffer) strips are grassed or forested areas through which runoff passes as sheet (or un-channelized) flow.
3) Detention basins may be dry or wet (sometimes referred to as extended dry basins and wet ponds, respectively).

With the original version of RUNQUAL, all runoff is routed through the BMPs. In the enhanced version of the model used within AVGWLF, the user can specify the extent to which the three BMPs are implemented within any given watershed. If the practices are used in combination, runoff is routed through them in the following order: infiltration retention, filter strips and detention basins.

C. Pine Creek AVGWLF and RUNQUAL Data Requirements

The following information was developed in order to run the RUNQUAL existing condition model of the Pine Creek Watershed.

1. Stormwater Management Pond Characteristics

As noted above, there are three basic types of BMPs that may be modeled by RUNQUAL. In the Pine Creek Watershed, the predominant type of BMP is the dry pond.

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[7] Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. *Water Resources Bulletin*, 23(3), pp. 471-478.

A large part of the modeling effort was the development of a GIS database of the existing BMPs in the watershed. Prior to this effort, no comprehensive database of stormwater management BMPs existed for the study area.

The first step in the process was to request that each of the fourteen municipalities in the Pine Creek Watershed provide information with respect to the location and type of BMPs located within their jurisdiction. In a few cases, the municipalities were able to provide a GIS layer, but many provided paper maps. Where no information was provided, significant dry ponds were located during a careful visual review of the Allegheny County 2004, five foot contour interval topographic mapping.

All of this information was used to create a single GIS coverage of the significant stormwater management dry ponds in the study area. Each of the BMPs was digitized in the GIS to determine and estimate its surface area and depth. From this information, an estimate of the ponds' volume was determined. The GIS database, once created, was used to determine the input data requirements for each of the thirteen sub basins that are being evaluated. The table below summarizes the SWM pond characteristics for the Pine Creek Watershed.

Table 3-1: Estimated Dry Pond Characteristics

Sub Basin Name	**Sub Basin Area**	**Number of Ponds**	**Surface Area**	**Avg. Depth**	**Volume Dry Ponds**
	(Square Miles)		(Square Feet)	(Feet)	(Cubic Feet)
Pine 1	0.429	0			
Pine 2	1.342	0			
Pine 3	10.263	26	247,630	5	1,224,938
Pine 4	1.304	1	3,600	3	8,311
Pine 5	10.770	61	1,044,860	5	5,106,472
Little Pine West	6.824	19	258,973	5	1,130,459
Little Pine East	5.720	17	135,205	5	622,052
Gourdhead & McCaslin	4.054	10	74,526	4	294,752
Crouse	4.350	16	212,593	6	1,190,371
Willow	4.427	10	80,826	5	341,195
Montour	5.352	12	172,362	6	945,474
North Fork	10.012	38	611,891	6	3,301,647
Fish Run	2.383	18	443,457	6	2,581,033
Totals	**67.229**	**228**	**3,285,923**	**5**	**16,746,703**

It was assumed for modeling purposes that each pond drained in 24 hours after a rainfall event and that 2% of the pond volume would be considered as dead storage. Dead storage is the volume of water contained in the pond 24 hours or more after a rainfall event. For the purpose of this study, it was also assumed that the dry ponds are not cleaned on a monthly basis.

2. Hardened /Stabilized Stream Banks

Stream bank erosion is a significant source of sedimentation in waterways. Therefore, an estimate of the amount of hardened or stabilized stream banks was determined from the evaluation of color orthophotographs of the watershed. The following table summarizes the results.

Table 3-2: Estimate of Hardened Stream Banks	
	Hardened Stream Bank
Sub-Basin	**Mile**
Pine 1	0.2
Pine 2	1.5
Pine 3	2.7
Total	**4.4**

3. Infiltration BMPs

For the purpose of the model, it was assumed that no significant infiltration BMPs are in place at this time. Under the new requirements listed in the Act 167 Plan, it is expected that this will change over time.

4. Buffer Strips

The types of cover adjacent to the waterway were determined from a cover type GIS layer that was created for the recent Act 167 Stormwater Management Plan. Areas located within 200 feet of the center of the stream that were determined to be pervious, such as woods or grass, were calculated for all thirteen sub-basins. In order to be conservative in our modeling, the area of pervious service was assumed to be 50% of the value of the total estimated pervious service within the two hundred foot stream buffer zone.

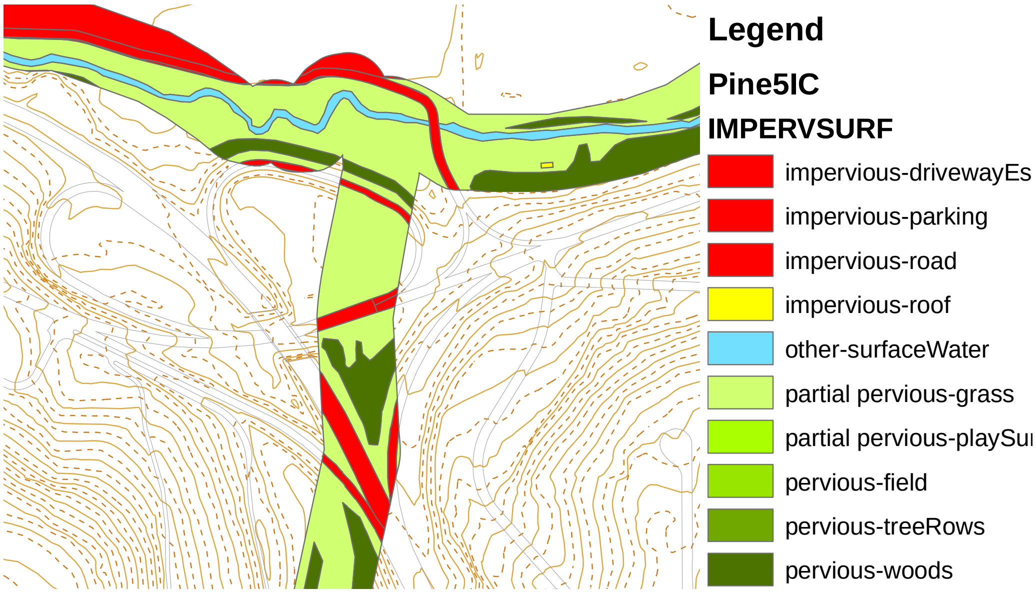


Figure 3-1: Example of Buffer Calculation

These values were then used to determine the fraction of the steam that would be considered as protected by a grass or wooded buffer zone. A summary of these statistics is provided in the following table.

Table 3-3: Surface Cover Within 200 Foot Stream Buffer Zone

Subbasin Name	Subbasin Area	Roof & Pavement	Water	Grass	Wooded	Unknown	% Impervious
	(Square Miles)	(Square Feet)	(Square Feet)	(Square Feet)	(Square Feet)	(Square Feet)	
Pine 1	0.429	85127	176747	361651	245826	168	9.8
Pine 2	1.342	1011880	503017	2404285	390738	2	23.5
Pine 3	10.263	2846839	2614694	10961234	8443453	0	11.4
Pine 4	1.304	195942	1888948	2297417	570151	16	4.0
Pine 5	10.770	1539706	482719	12388767	7871746	0	6.9
Little Pine West	6.824	1174452	511683	8794274	3131918	0	8.6
Little Pine East	5.720	532355	206736	5948309	3817261	0	8.6
Gourdhead& McCaslin	4.054	1022841	56728	3274923	3893430	0	6.5
Crouse	4.350	606753	0	4685804	3574470	0	6.8
Willow	4.427	248334	264146	4708372	4914459	0	2.5
Montour	5.352	382479	520757	5099556	10329004	0	2.3

North Fork	10.012	771560	3295459	11126076	10007806	0	3.1
Fish Run	2.383	223979	47521	2994701	1983939	0	4.3
Totals	**67.23**	**10642245**	**10569154**	**75045369**	**59174200**	**185**	**6.8**

5. Discharge of Sewage Treatment Plants

Research was completed to determine the location, discharge and effluent limits of the publicly owned sewage treatment works (POTWs) in the study area. The model uses these values to determine the effect of the treated discharge on the total nitrogen and phosphorous levels in the area downstream of the sewage treatment plant. A summary of the values used in the model are provided in the table below.

Table 3-4: NPDES Permits for Pine Creek

NPDES Permit No.	**Owner**	**Plant Name**	**Location**	**Capacity (MGD)**
PA0028177	McCandless Township Sanitary Authority	A&B STP	Arden Drive 15237	0.4
PA0027669	McCandless Township Sanitary Authority	Pine Creek STP	2160 Wildwood Rd. 15044	6.0
PA0025992	McCandless Township Sanitary Authority	Longvue No. 1 STP	1275 Hazlett Rd. 15237	1.2 (in future 2.1)
PA0043729	Hampton Township Sanitary Authority	Allison Park STP	2536 Toner Ave. 15101	3.2
			Total	10.8

6. Combined Sewer Overflow

The enhanced RUNQUAL component of the AVGWLF model allows for the modeling of wet weather overflow from the POTWs. It was assumed that each of these facilities may experience wet weather overflows when the precipitation for a 24 hour period exceeds 1.5 inches/day. The model is not able to model sewage overflows that are not located at the sewage treatment plant. This means that the model does not capture the impacts of the multiple sewer overflows in the watershed. However, the only combined sewer community in the watershed is Etna Borough. Etna is located at the bottom of the watershed. The remainder of the municipalities in the watershed are separately sewered.

There is evidence that two of the four POTWs in the Pine Creek Watershed have experienced problems meeting their permit requirements. A report prepared by PennEnvironment titled, *Troubled Waters: An Analysis of 2005 Clean Water Act Compliance*,[8] noted violations at the Pine Creek and Allison Park sewage treatment plants. It should also be noted the McCandless Township Sanitary Authority (MTSA) is in the process of increasing the capacity of its Longvue No.1 STP from 1.2 to 2.1 million gallons per day (mgd). This investment is to increase capacity at the plant and also to better handle wet weather flow increases.

7. Street Sweeping

Street sweeping can remove sediment and debris from entering waterways. For the purpose of the model, it was assumed that the streets are swept three times per year.

D. Model Results for the Watershed

A summary of the model results for the entire Pine Creek Watershed is provided below. Table 3-5 summarizes the results of the RUNQUAL model for both the natural state and the existing conditions. Complete summaries of the model inputs and outputs are provided in Appendices 1 and 2.

Table 3-5: Model Results for Pine Creek

	Natural State	Existing Conditions	% Change
Watershed Area (acre)	42830	42830	
Stream Flow (inches per year)	19.28	22.84	18.5%
Stream Flow (acre - feet)	68813	81519	
Stream Flow (liters)	84,846,775,580	100,513,503,851	
Total Suspended Solids (pounds per year)	40,560,219	43,789,714	8.0%
Total Suspended Solids (mg/l)	217	198	-8.9%
Dissolved Nitrogen (pounds per year)	122,909	593,842	
Dissolved Nitrogen (mg/l)	0.66	2.68	306.1%
Total Nitrogen (pounds per year)	148,183	631,153	
Total Nitrogen (mg/l)	0.79	2.85	260.8%
Dissolved Phosphorus (pounds per year)	3,237	70,550	
Dissolved Phosphorus (mg/l)	0.02	0.32	1500%

[8] Leavitt, Christy, PennEnvironment Research & Policy Center. *Troubled Waters: An Analysis of 2005 Clean Water Act Compliance*. October 2007.

Total Phosphorus (pounds per year)	9,021	77,539	
Total Phosphorus (mg/l)	0.05	0.35	600%

A summary of existing conditions for all of the sub basins is found in Appendix 3. According to RunQUAL, the sub basins most significantly impacted by Total Suspended Solids, Nitrogen, and Phosphorus are:

- Pine 3 (mid- lower main stem of Pine Creek and receiving body of several other sub basins)
- West Little Pine
- Pine 5
- North Fork Pine Creek

1. Stream Flow

As expected, the increase in urbanization and impervious cover has reduced evapotranspiration and ground water infiltration while increasing runoff and stream flow. As a result less water is available to recharge the waterway during dry periods and there is increased flow during storms. Higher stream flows affect channel size and shape, which ultimately impact erosion rates.

2. Total Suspended Solids

Under natural conditions, Total Suspended Solids (TSS) are carried into the waterway. Increased levels of suspended solids can affect aquatic life by smothering aquatic invertebrates and fish eggs, as well as affecting the ability of fish to breathe and eat.

The model indicates that the added runoff into the waterway and subsequent increase in stream volume due to urbanization has increased the amount of TSS in the watershed's existing state, but decreased the concentration of solids per volume of water. The 8% increase in TSS is a modest amount and may reflect an underestimate of the true amount by the model. The amount of suspended solids can vary greatly, particularly during periods of construction and actively changing stream channels. None of the volunteer monitoring efforts to date have included a measurement of TSS; therefore no quantitative comparison can be made with the model. However, the Riparian and Stream Channel Assessment has noted areas that receive too much stormwater and suffer from excessive erosion.

3. Nitrogen

Nitrogen is an essential nutrient for aquatic life. However, an increase in nitrogen, under the right conditions, can set off undesirable events in a stream, including accelerated plankton and aquatic plant growth, a process called eutrophication. The death and decomposition of algae and aquatic plants by oxygen consuming bacteria results in low dissolved oxygen causing the death of fish, invertebrates, and other aquatic animals.

There are many natural sources of nitrogen such as atmospheric deposition, and plant and animal life. However, nitrogen is added to these natural sources from wastewater treatment plants, sanitary sewer overflows, and runoff from fertilized lawns and agricultural areas.

Although the model's predicted level of nitrogen (2.85 mg/l) for the existing or developed state is still within the guidelines noted for the PA SEC Water Quality Training Manual[9] (see Table 2-2), its increase has more than doubled from its natural state. No Nitrate data were reported during the Assessment, so no comparison can be made with field measurements.

4. Phosphorous

Phosphorous is also an essential nutrient for aquatic life. As with nitrogen, excess levels of phosphorus can lead to eutrophication and depleted oxygen levels when the excess plants and algae decompose.

There are many natural sources of phosphorus such as plant and animal life, soil, and rocks. Phosphorus is added to these natural sources from wastewater treatment plants, sanitary sewer overflows, and runoff from fertilized lawns and agricultural areas.

The predicted levels of phosphorous are dramatically higher in the developed state, 0.35 mg/l, versus 0.05 mg/l in the natural state. As mentioned in Table 2-2, the PA Senior Environmental Corps Water Quality Training Manual reports a maximum Phosphorus level of 0.03 mg/l in healthy streams. The results of the model are consistent with the volunteer monitoring conducted for the Assessment, which showed high results for total phosphates throughout the watershed.

E. Evaluation of Pollution Load Results by Source

It becomes apparent from the evaluation of the pollution loading by source (point source, stream bank, subsurface, open land and developed land) model results that nonpoint source nutrient pollutants from runoff related to land development is a small component of the overall pollutant load in the watershed. See Table 3-6.

It should be noted that nonpoint source BMPs will affect only the streambank and developed land sources. The point source, subsurface and open land sources are not improved by the implementation of stormwater and stream bank stabilization BMPs.

[9] The Pine Creek Watershed Assessment, Protection, and Restoration Plan noted that the PA Code criteria for nitrate were for potable water supplies and, therefore, not deemed appropriate. The PA SEC Water Quality Training Manual criteria were then substituted as the guidelines to follow.

Table 3-6: Evaluation of Pollution Load by Source		
Source	**Natural (pounds/year)**	**Existing (pounds/year)**
Point Source		
Dissolved Nitrogen	0	488,989
Total Nitrogen	0	488,989
Dissolved Phosphorus	0	66,360
Total Phosphorus	0	66,360
Streambank		
Total Suspended Solids	38,800,000	41,709,267
Total Nitrogen	1,957	2,086
Total Phosphorus	3,914	4,171
Subsurface		
Dissolved Nitrogen	110,375	94,941
Total Nitrogen	110,347	94,941
Dissolved Phosphorus	2,906	2,500
Total Phosphorus	2,906	2,500
Open Land		
Total Suspended Solids	1,421,275	838,148
Total Nitrogen	23,722	35,225
Total Phosphorus	1,898	2,818
Developed Land		
Total Suspended Solids	0	1,242,298
Dissolved Nitrogen	0	8,116
Total Nitrogen	0	8,258
Dissolved Phosphorus	0	1,177
Total Phosphorus	0	1,186

1. Total Suspended Solids

The following graphs illustrate the total pounds of suspended solids generated on an annual basis from each source (streambank, open land and developed land) in both the natural and existing conditions. The majority of these solids are from eroded streambanks. The model results have accounted for the 4.35 miles of stabilized (hardened) streambanks that exist in the watershed. Without these stabilized streambanks, the existing TSS would be higher.

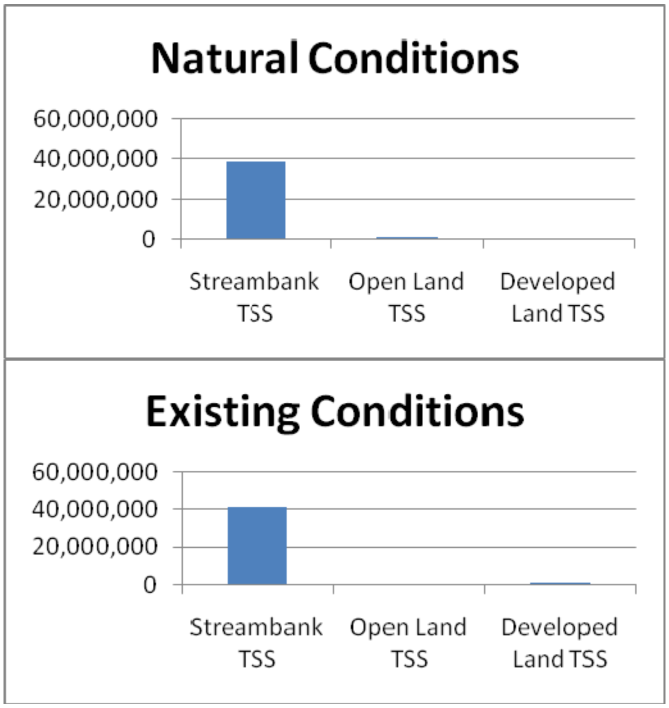


Figure 3-1: Total Suspended Solids generated yearly

2. Nitrogen & Phosphorus

Nitrogen and phosphorus are primarily produced by point source discharges from sewage treatment plants. Note that the nitrogen and phosphorous loads from the subsurface flows decrease after development. This is because the addition of impervious cover reduces the amount of water that is able to enter the groundwater table.

The following graphs illustrate the nitrogen (TN) loads for each of the conditions modeled.

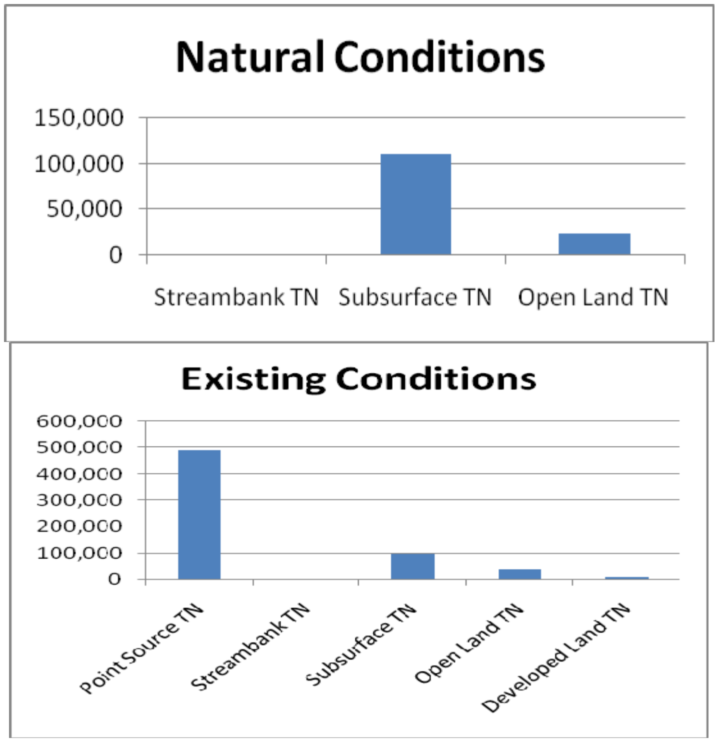
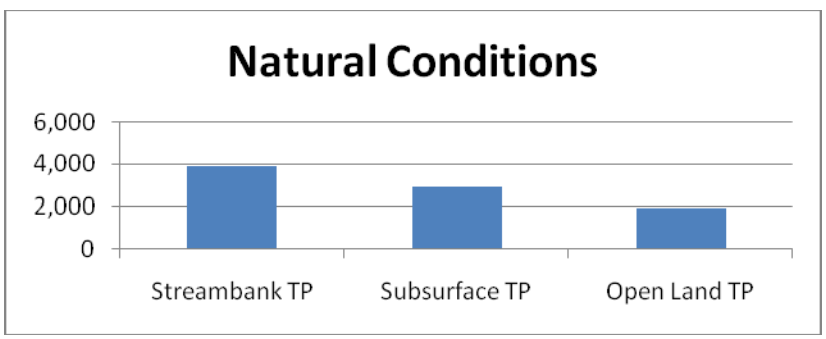


Figure 3-2 Total Nitrogen generated yearly

The next two graphs illustrate the phosphorous (TP) loads for each of the conditions modeled.



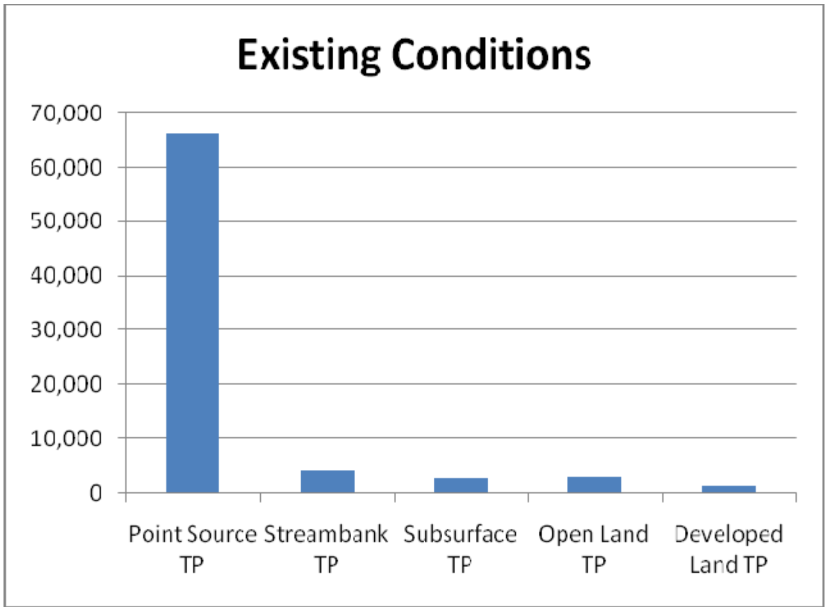


Figure 3-3: Total phosphorus generated yearly

It is apparent from an evaluation of the model results that the primary source of the nitrogen and phosphorous loads are from the legal discharge of sewage treatment plants in the watershed. Changes to these discharges are out of the scope of this study.

Chapter 4: Recommendations for Pollution Load Reductions

As noted in the previous chapters, the Pine Creek Watershed has water quality impairments due the effects of urbanization. Areas lower in the watershed were developed prior to the requirement for stormwater management peak rate controls, which were first required by the Act 167 Stormwater Management Plan of 1983. Water quality BMPs were not a requirement in the watershed until the implementation of the municipal separate storm sewer systems (MS4) requirements in 2004. Therefore, although the impervious cover in the watershed is estimated to be 8.3%, there is not a proportionate level of stormwater management BMPs in the watershed to control this amount of impervious cover. As would be expected, this deficit of stormwater BMPs has resulted in more severe flooding and water quality impairments in the watershed. This section will provide guidance on methods to protect and restore the watershed.

A. Enhanced Stormwater Management Ordinance Requirements

The municipalities in the Pine Creek Watershed and three other neighboring watersheds in the North Hills area of Allegheny County recently completed a revision to their existing Act 167 Stormwater Management Ordinance for the Pine Creek, Girtys Run, Deer Creek and Squaw Run Watersheds. The revised Stormwater Management Ordinance was adopted by each of the municipalities within the watershed in October 2008.[10]

The development of the updated ordinance was overseen by the Watershed Plan Advisory Committee (WPAC). The WPAC was made up of individuals from the North Area Environmental Council, the Pennsylvania Environmental Council, PA DEP, the Allegheny County Conservation District, the Allegheny County Department of Economic Development, the North Hills Council of Governments and municipal managers, planners, and engineers.

There are many significant improvements contained within the new regional Act 167 Stormwater Management Ordinance, such as:

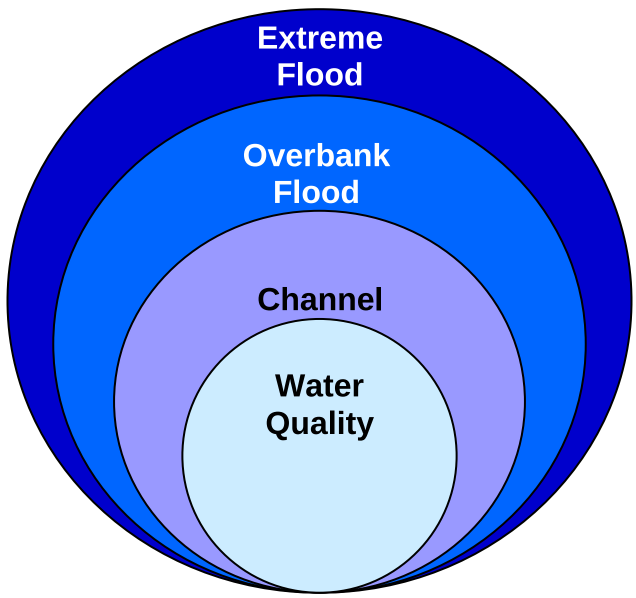
- The incorporation of water quality and infiltration standards,
- Provision of credits for the use of non-structural best management practices, including: the protection of existing wooded and natural areas, the use of stream buffers, the use of enhanced swales and infiltration practices, and the use of low density development practices,
- Continued 2, 10, 25 and 100 year storm peak rate reduction requirements,
- The application of stormwater management requirements to all sites having a disturbed area of greater than 400 square feet,
- Stormwater management requirements for existing sites that undergo redevelopment,
- Preventing the waiving of ordinance requirements by the local municipality and requiring that they must be approved by Allegheny County or its designee,
- The development of a standardized BMP design method for small projects.

[10] Detailed information about the Act 167 Plan can be found at www.ross.pa.us

The implementation of the Act 167 Plan will prevent further increases in pollution and provide for decreases in pollutants as areas are redeveloped.

1. Revised Stormwater Management Requirements

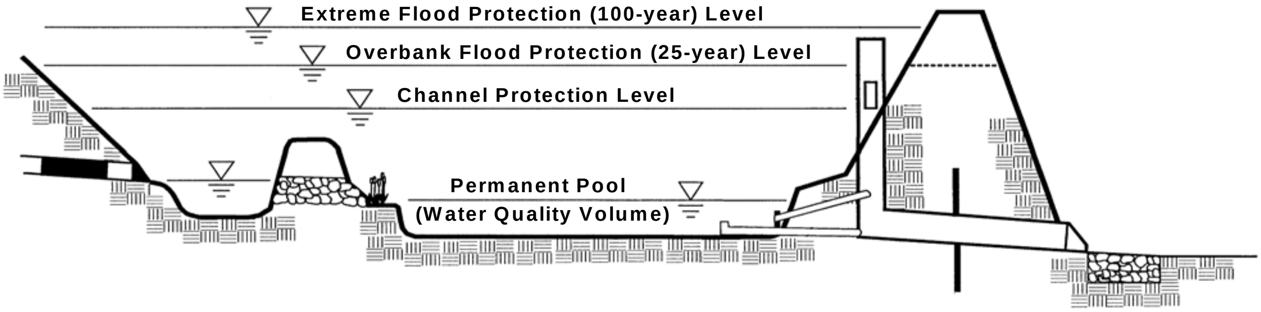
In the past, the Act 167 Stormwater Management Ordinance for the watershed addressed peak rate control only and not water quality. The revised Act 167 Ordinance now includes the following unified stormwater design approach, which uses four criteria in its development (water quality, channel, overbank flood, and extreme flood). This approach was developed by the State of Maryland and the Center for Watershed Protection and is the basis of many of the State Programs reviewed.



Representation of the Unified Stormwater Sizing Criteria
From the Georgia Stormwater Management Manual[11]

[11] http://www.georgiastormwater.com/vol1/gsmmvol1.pdf

The figure below shows how these volumes would be stacked in a typical stormwater (wet) pond designed to handle all four criteria. The wet ponds are designed to retain a permanent pool of water which will have water quality benefits as well flood control benefits.



Unified Sizing Criteria Water Surface Elevations in a Stormwater (Wet) Pond
From the Georgia Stormwater Management Manual

<u>Description of Stormwater Sizing Criteria</u>

The recently developed Act 167 Plan requires that the region adopt methods in use in other states that are easy to calculate and verify. A summary of the recommended methods are provided in Table 4-1 below.

Table 4-1: A Summary of Recommended Methods of Calculations

Sizing Criteria	**Description of Stormwater Sizing Criteria**
Water Quality Volume (WQ_v) (acre-feet)	**$WQ = [\ P(R_v)(A)\ ] / 12$** Where; P= rainfall depth in inches and is equal to 1.0" R_v = volumetric runoff coefficient = 0.05 + 0.009(I) where I is percent impervious cover A = site area in acres
Channel Protection Storage Volume (extended detention) (Cp_v)	Cp_v = 24 hour extended detention of post-developed **one-year**, 24 hour storm event.
Overbank Flood Protection Volume (Q_p)	Controlling the post development peak discharge rate from the ten-year storm event to the pre development rate (Q_{p10}), using the specified Act 167 release rate percentage for the sub-basin.

Extreme Flood Volume (Q_f)	Controlling the post development peak discharge rate from the 100-year storm event to the pre development rate (Q_{p100}), using the specified Act 167 release rate percentage for the sub-basin.

Proposed Method to Calculate Water Quality Volume (WQ_v)

The Georgia Manual states "Hydrologic studies show that small-sized, frequently occurring storms account for the majority of rainfall events that generate stormwater runoff. Consequently, the runoff from these storms also accounts for a major portion of the annual pollutant loadings. Therefore, by treating these frequently occurring smaller rainfall events and a portion of the stormwater runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area."

The Water Quality Volume (WQ_v) standard requires structural control facilities to treat runoff from these small frequent storms and also provides a "first flush" treatment of larger storm events. The Water Quality Treatment Volume used was determined to be the runoff generated from the 90th percentile storm event (i.e., the storm event that is greater than 90% of the storms that occur within an average year).

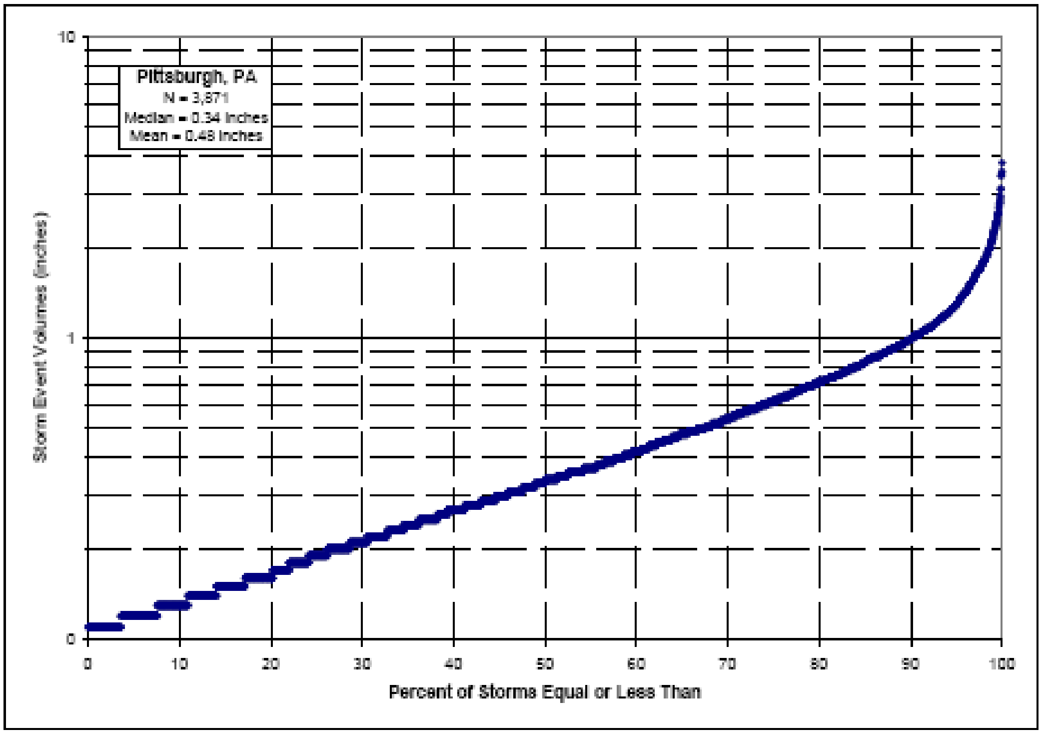


Figure 4-1: Synoptic Precipitation Analysis for the ALCOSAN Service Area

Based on a rainfall analysis performed by the Allegheny County Sanitary Authority (ALCOSAN),[12] a value of one (1”) inch for the 90th percentile storm was noted. A stormwater management system designed for the WQ_v will treat the runoff from all storm events of one (1”) inch or less, as well as the first one (1”) inch of runoff for all larger storm events. The Water Quality volume is directly related to the amount of impervious cover and is calculated using the formula in the following:

$$WQ_V = \frac{1'' R_V A}{12}$$

where: WQ_v = water quality volume (in acre-feet)
R_v = 0.05 + 0.009(I) where I is percent impervious cover
A = total area of site being developed in acres

Using the percent impervious area as the basis for calculating the water quality treatment volume promotes the use of straightforward volume calculations. The total impervious area of a site is determined based on final project site plans, not on pre-existing conditions.

The developer must indicate how the WQ_v will be achieved by the use of structural and non structural BMPs. Where possible, it is recommended that a portion of the **total** WQ_v be infiltrated.

Recharge Volume (Infiltrated Volume)

In order to restore ground water recharge and stream base flows, the following criteria developed by the State of Massachusetts are used in the revised Act 167 Ordinance.

- Recharge to Groundwater

The prescribed stormwater runoff volume to be recharged to groundwater should be determined using the existing (pre-development) soil conditions as noted in the U.S. Natural Resources Conservation Service County Soils Survey,[13] onsite soil evaluation, or other geologic information, and these rates:

Hydrologic Group	Volume to Recharge (x Total Impervious Area)
A	0.40 inches of runoff
B	0.25 inches of runoff
C	0.10 inches of runoff
D	waived

[12] Synoptic Precipitation Analysis for the ALCOSAN Service Area, February 2003
[13] A Hydrologic Soils Group Map for the North Hills area of Allegheny County was developed during the Act 167 update and is available in the ArcGIS format.

Roof runoff (except for certain metal roofs) may be infiltrated, and any infiltrated volume may be subtracted from the total WQ_v.

Different recharge values may be used, provided the proponent makes a clear demonstration that the recharge rate differs from the listed values based upon soils, precipitation, and evapotranspiration.

- Recharge / Infiltration Design Considerations

  - In general, roof areas should be considered for infiltration.
  - Any infiltrated volume may be subtracted from the total WQ_v
  - Infiltration should not be considered for sites or areas of sites that have activities that may allow pollution to be infiltrated. For example, the use of infiltration for the runoff of a service station paved lot would not be appropriate, although roof water from the service station may be infiltrated.
  - Infiltration should only be used when, in the opinion of a Professional Engineer, it will not contribute to slope instability or cause seepage problems into basements or developed down gradient areas.
  - Examples of infiltration include rain gardens and porous pavements

Volume Reduction Methods

The developer may obtain credits for the use of nonstructural BMPs using the procedures outlined below. These methods of credits noted in the Georgia Stormwater Manual (August 2001)[14] and further refined in the North Central Texas Council of Governments Stormwater Manual[15] are recommended. It is further recommended that the design of BMPs be as per the requirements contained in the Pennsylvania's Stormwater Best Management Practices Manual (PaBMP Manual, December 2006).

- Volume Reduction Method #1: Natural Area Conservation

A water quality volume reduction can be taken when undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this method, a designer would be able to subtract the conservation areas from the total site area when computing the water quality protection volume. An added benefit is that the post-development peak discharges will be smaller, and hence, water quantity control volumes will be reduced due to lower post-development curve numbers or rational formula "C" values.

- Volume Reduction Method #2: Stream Buffers

This reduction can be taken when a stream buffer effectively treats storm water runoff. Effective treatment constitutes treating runoff through overland flow in a naturally vegetated or forested buffer. Under the proposed method, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality protection volume

[14] http://www.georgiastormwater.com/vol1/gsmmvol1.pdf
[15] http://www.iswm.nctcog.org/

requirements. In addition, the volume of runoff draining to the buffer can be subtracted from the stream bank protection volume. The design of the stream buffer treatment system must use appropriate methods for conveying flows above the annual recurrence (1-yr storm) event.

- Volume Reduction Method #3: Enhanced Swales

This reduction may be taken when enhanced swales are used for water quality protection. Under the proposed method, a designer would be able to subtract the areas draining to an enhanced swale from total site area, when computing water quality protection volume requirements. An enhanced swale can fully meet the water quality protection volume requirements for certain kinds of low-density residential development (see Volume Reduction Method #5). An added benefit is the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

- Volume Reduction Method #4: Overland Flow Filtration/Groundwater Recharge Zones

This reduction can be taken when "overland flow filtration/infiltration zones" are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or "rain garden" areas. If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality protection volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

- Volume Reduction Method #5: Environmentally Sensitive Large Lot Subdivisions

This reduction can be taken when a group of environmental site design techniques are applied to low and very low density residential development (e.g., 1 dwelling unit per 2 acres [du/ac] or lower). The use of this method can eliminate the need for structural storm water controls to treat water quality protection volume requirements. This method is targeted towards large lot subdivisions and will likely have limited application.

Channel Protection Volume (CP_v)

The Georgia Stormwater Manual provides the following: "The increase in the frequency and duration of bankfull flow conditions in stream channels due to urban development is the primary cause of stream bank erosion and the widening and downcutting of stream channels. Therefore, channel erosion downstream of a development site can be significantly reduced by storing and releasing stormwater runoff from the channel-forming runoff events (which correspond approximately to the 1-year storm event) in a gradual manner to ensure that critical erosive velocities and flow volumes are not exceeded."

The Channel Protection sizing criterion specifies that 24 hours of extended detention be provided for runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume needed for 1-year extended detention, or Channel Protection Volume (denoted CP_v), is roughly equivalent to the required volume needed for peak discharge control of the 5-year to10-year storm.

The reduction in the frequency and duration of bankfull flows through the extended detention of the CP_v is presumed to reduce the bank scour rate and severity. Therefore, these criteria should be applied wherever upstream development can increase the natural flows to downstream feeder streams, channels, ditches and small streams. It might be waived by a community for sites that discharge directly into larger streams, rivers, wetlands or lakes where the reduction in the smaller flows will not have significant impact on stream bank or channel integrity.

This criterion should be paired with an effective stream bank inspection and restoration program designed to identify and protect any locations where erosion occurs, through the use of bio-engineering and other stream bank protection and stabilization techniques.

2. Estimated Water Quality Volume Requirement for Pine Creek

By using the watershed impervious cover information developed for the Act 167 Study and the stormwater management pond inventory prepared for the current Watershed Implementation Plan (and ongoing Act 167 work), it is possible, for the first time, to quantify both the amount of impervious cover, the estimated storage contained in the existing stormwater management ponds, and also determine an estimate of the water quality volume (WQv) requirements for the watershed. The table below summarizes these results for each of the sub-basins within the Pine Creek Watershed.

The estimate of the WQv needs for the watershed is an important metric with respect to controlling nonpoint source pollutants in the watershed. If the additional WQv BMPs were added in the watershed these BMPs would significantly reduce nonpoint source runoff in the watershed. An evaluation of the water quality benefits expected by adding additional WQv BMPs is provided later in this report.

Table 4-2 Water Quality Volume Requirement by Sub Basin						
Sub Basin Name	**Sub Basin Area**	**% Impervious**	**Number of SWM Ponds**	**Rv**	**WQv**	**Volume of Existing Dry Ponds**
	(sq. mile)				(CF)	(CF)
Pine 1	0.42927	23.1%	0	0.2575	256,827	0
Pine 2	1.34160	10.8%	0	0.1468	457,448	0
Pine 3	10.26300	11.3%	26	0.1520	3,624,775	1,224,938
Pine 4	1.30360	8.2%	1	0.1234	373,744	8,311
Pine 5	10.77000	11.5%	61	0.1534	3,838,439	5,106,472
Little Pine West	6.82350	15.2%	19	0.1872	2,967,980	1,130,459
Little Pine East	5.71980	3.0%	17	0.0774	1,028,685	622,052
Gourdhead/ McCaslin	4.05363	5.6%	10	0.1003	944,848	294,752
Crouse	4.35020	9.1%	16	0.1323	1,337,131	1,190,371
Willow	4.42720	4.9%	10	0.0942	968,567	341,195
Montour	5.35240	3.5%	12	0.0818	1,016,715	945,474
North Fork	10.01200	5.9%	38	0.1027	2,388,360	3,301,647
Fish Run	2.38270	7.4%	18	0.1163	643,875	2,581,033
Entire Pine Watershed	67.22890	8.30%	228	0.1247	19,476,417	16,746,703

The number of stormwater management ponds (SWM) was determined from maps provided by some of the 14 municipalities in the watershed and from a visual review of the Allegheny County 2004 five foot contour interval topographic mapping.

It is important to note that the existing stormwater management dry ponds were designed to control peak flows to reduce flooding. They were not designed as water quality BMPs. Still the data allow us to review the volume of existing storage available with the recommended water quality treatment (WQv) volume. Because the existing stormwater management ponds provided no significant water quality benefit, the total WQv deficit needed to remove pollutants from runoff during rainfall events is approximately 19 million cubic feet. This deficit is understandable because much of the area in the watershed was developed prior to the requirements for water quality BMPs.

It is apparent that in order to control the detrimental effect of impervious cover on the watershed that a significant amount of water quality control BMPs would need to be added to the watershed. The retrofit of existing SWM ponds is a likely place to start.

B. Stormwater Dry Pond Retrofits

Although the new Act 167 Stormwater Management Ordinance will address many of the problems related to new development and provides new stormwater management requirements on existing sites as they undergo redevelopment, an effort will need to be made to address the BMP deficit by looking for opportunities to improve the existing BMPs and to add additional BMPs within the watershed. This approach has been labeled "retrofitting" by the Center for Watershed Protection (CWP). Their manual, *Urban Stormwater Retrofit Practices*, published in 2007 was used as guidance to develop an approach for the improvements needed in the study area. The CWP manual outlines the recommended steps during a retrofit process. A table from that manual is reproduced and reformatted below. Although a complete retrofit analysis is outside the scope of this report, the concepts in the manual will be used to address the water quality volume (WQv) treatment deficit in the watershed. For this study the retrofit being evaluated is the conversion of existing dry SWM ponds to wet SWM ponds.

Table 4-3: Center for Watershed Protection's Purpose of the Eight Steps in the Stormwater Retrofitting Process[16]

Step and Purpose	**Key Tasks**
Step 1: Retrofit Scoping Refine the retrofit strategy to meet local restoration objectives	• Screen for subwatershed retrofit potential • Review past, current, and future stormwater • Define core retrofitting objectives • Translate into minimum performance criteria • Define preferred retrofit treatment options • Scope out retrofit effort needed
Step 2: Desktop Retrofit Analysis Search for potential retrofit sites across the subwatershed	• Secure GIS and other mapping • Conduct desktop search for retrofit sites • Prepare base maps for RRI
Step 3: Retrofit Reconnaissance Investigation (RRI) Investigate feasibility of retrofit sites in the field	• Advanced preparation • Evaluate individual sites during RRI • Finalize RRI sheets back in office
Step 4: Compile Retrofit Inventory Develop initial concepts for best retrofit sites	• Complete storage retrofit concept designs • Finalize on-site retrofit delivery methods • Assemble retrofit inventory
Step 5: Retrofit Evaluation and Ranking	• Neighborhood consultation

[16] Table 4.1 from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices*, 2007

Choose the most feasible and cost effective sites	• Develop retrofit screening criteria • Create retrofit project priority list
Step 6: Subwatershed Treatment Analysis Determine if retrofits can achieve subwatershed restoration objective	• Compute pollutant removal by storage retrofits • Compute pollutant removal by on site retrofits • Compare against restoration objective
Step 7: Final Design and Construction Assemble design package to lead to successful retrofit construction	• Secure environmental permits • Obtain landowner approval and easements • Perform special engineering studies • Put together final design package • Contract and project management
Step 8: Inspection, Maintenance & Evaluation Ensure retrofits are working properly and achieving subwatershed objectives	• Construction inspection • Retrofit maintenance • Project tracking and monitoring

1. Evaluation of the Benefits of the Water Quality Volume BMP Approach

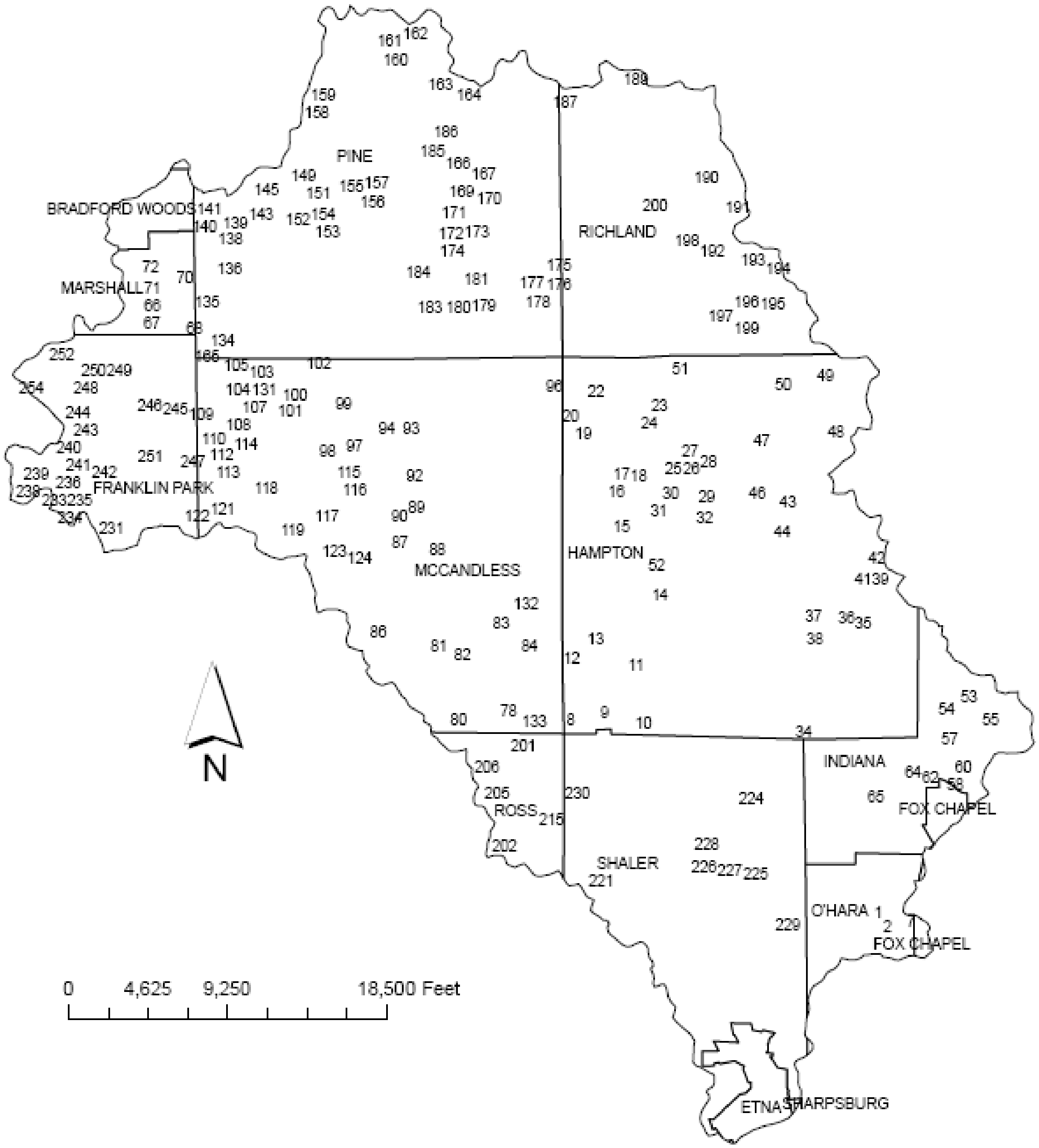
Several types of BMPs may be used to provide the WQv components needed to improve the water quality in the watershed. These include constructed stormwater management wet ponds, bioretention (rain gardens), stream buffers, stream channel stabilization, streambank stabilization and protection of existing steep slopes and wooded areas.

Highly urbanized areas in the watershed, particularly the Borough of Etna and the abutting portions of Shaler Township, are not suitable for the construction of wet ponds due to the lack of open area and therefore methods such as the reconstruction of the existing storm sewer system to include bioretention concepts will be required. It should be noted that the Borough of Etna is a combined sewer (CS) area and that the retrofitting of the existing stormwater infrastructure may be an important component of the Borough's combined sewer overflow (CSO) control efforts. The Borough's plans to address this issue are described later in this chapter.

Many of the remaining portions of the watershed have open areas and existing stormwater management ponds. The existing SWM ponds are dry ponds that are not considered to provide water quality improvement. These dry pond sites could be reconstructed as stormwater management wet ponds and in some cases resized to increase the existing flood protection storage volume in the watershed. It is proposed that many of the existing stormwater management dry ponds be converted to wet ponds. Wet ponds have been shown to provide significant water quality improvements.

As previously noted, the location and size of the existing SWM ponds within the watershed have been determined. Map 4-1 shows the number of SWM ponds by subbasin. The estimated water quality volume (WQv) required to reduce the WQ impacts created by the urbanization of the

Pine Creek Watershed was also determined. The total estimated WQv needed to mitigate the impacts of development was calculated to be 19,479,417 cubic feet.



Map 4-1: Existing SWM Dry Pond Locations

It will be assumed for the basis of this estimate that approximately 25 percent, or 4,186,676 cubic feet, of the existing dry pond storage will be converted to wet ponds. It should also be noted that extended detention ponds may also be a viable alternative in the watershed. It also will be assumed that each pond will be retrofit using the following strategies:

- Replacement or modification of the existing raisers
- Increasing pond storage by deepening or raising the embankment
- The addition of forebays to the ponds
- Outfall stabilization when needed

Existing Dry Storage	**Retrofit %**	**Retrofit Volume**
(cubic feet)	(%)	(cubic feet)
16,746,703	25%	4,186,676

It is also assumed that each of the existing SWM dry ponds will have the total storage volume increased by the same amount so that the peak flow protection provided by each pond will not be reduced. In addition to the pond retrofits noted above, it was also previously determined that in order to provide the needed WQv, an additional 15,289,741 cubic feet of new WQv would need to be constructed.

The following table summarizes the information that was used to run the AVGWLF RunQual model to determine the benefit of the proposed BMPs. Note that the input parameters were converted to the metric system to run the model.

Table 4-4: AVGWLF RunQUAL Input Parameters to Evaluate BMP Benefits

BMP Storage Type	Cubic Feet
Existing dry storage (detention basin volume)	16,746,703
Proposed total basin volume with 25% storage increase to existing ponds	20,933,379
Retrofit 25% to wet storage (WQv)	4,186,676
Proposed new wet storage (WQv)	15,289,741
Proposed total detention volume	36,223,120
Proposed total wet storage volume (WQv)	19,476,417
Existing basin surface area	3,285,923
Proposed basin surface area	7,107,452

Evaluation of WQv BMP Benefits (AVGWLF RunQual Model)

After running the AVGWLF, it was found that the RunQual component of the model did not accurately predict the benefits of enlarging the SWM Detention Basins. Table 4-5 shows that TSS loading increased when additional BMPs were implemented and the phosphorous levels did not decline. Also, the RunQual component appeared to over predict nitrogen removal. The model predicted that the TN would drop from 8,258 to 1,028 pounds per year, a reduction of 88%. A typical nitrogen removal rate is more on the order of 30%.

Table 4-5: AVGWLF RunQual Model Results for Pollutant Load Reductions from Developed Land Area (Pounds/Year)

	Natural Conditions	Existing Conditions	With WQv BMPs Added
Developed Land TSS	0	1,242,298	1,287,511
Developed Land DN	0	8,116	1,010
Developed Land TN	0	8,258	1,028
Developed Land DP	0	1,177	1,117
Developed Land TP	0	1,186	1,186

In summary, it appears that the RunQual component did not accurately predict the benefits of the addition of wet ponds. These inconsistencies were reported to the RunQual developer. This is a fault of the model; the WQv BMP approach proposed has been shown to significantly reduce pollution loading when applied. The AVGWLF model did however provide reasonable estimates with respect to pollutants that are expected to runoff from the various land uses modeled.

Evaluation of WQv BMP Improvements (Center for Watershed Protection Approach)

Because of the inconsistent results offered by the RunQual model, a reevaluation of the watershed was performed using a method developed by the Center for Watershed Protection (CWP). The CWP is a nonprofit organization located in Ellicott City Maryland that is dedicated to the study and protection of the nation’s waterways. A summary of the AVGWLF results with respect to the predicted pollutant loads from various nonpoint land uses is provided below. These will be assumed to be the existing pollutant loads in the CWP approach.

Table 4-6: AVGWLF Model Results for Developed Area by Land Use Type

Land Use	**Area (Acres)**	**Pollutant Load (Pounds per year)**				
		TSS	**DN**	**TN**	**DP**	**TP**
Low Density Mixed	208	3,200	130.7	130.7	17.2	17.2
Medium Density Mixed	801	76,803	408.8	408.8	53.9	53.9

High Density Mixed	3,336	570,457	461.3	461.3	60.9	60.9
Low Density Residential	4,601	106,416	2,457.3	2,507.7	297.7	300.2
Medium Density Residential	8,113	438,780	4,485.6	4,577.6	722.4	728.5
High Density Residential	524	46,642	171.9	171.9	25.3	25.5

Assuming that the 19,479,417 CF of WQv is installed, an estimate of the pollution load reductions of total suspended solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) for the proposed retrofits will be established using the "Simple Method" developed by the CWP. Details of this method are provided in the CWP's *Urban Stormwater Retrofit Practices Manual,* which is included in this document as Appendix 4.

Post retrofit pollution loading can be calculated using the following formula:

$$L_{post} = L_{pre} * [1-(RR)]$$

Where
L_{post} = Annual pollutant load exported from the site after stormwater retrofit (pounds/yr)
RR = Adjusted removal rate (%) calculated in Step 4
L_{pre} = Annual pollutant load exported from the site before the stormwater retrofit (pounds/year)

According to the CWP *Urban Stormwater Retrofit Practices Manual*, the wet pond method proposed is expected to reduce the TSS, TN, and TP at the rates outlined in the table below. The values in the column titled "Removal Rate Used to Determine Estimate" were used for the purpose of this evaluation. Details of the removal rates can be found in Appendix 5.

Table 4-7: Pollutant Removal Rate in Wet Ponds		
Pollutant	**Removal Rate Range**	**Removal Rate Used to Determine Estimate**
TSS	60 to 90%	80%
TN	15 to 40%	30%
TP	40 to 75%	50%

Pollutant load reduction of the retrofit can be calculated using the following formula:

$$\mathbf{LR} = \left| \mathbf{L_{post}} - \mathbf{L_{pre}} \right|$$

Where:
LR = Absolute value of the annual pollutant load removed by the proposed retrofit (pounds/year)
$\mathbf{L_{post}}$ = Annual pollutant load exported from the site after stormwater retrofit (pounds/year)
$\mathbf{L_{pre}}$ = Annual pollutant load exported from the site prior to stormwater retrofitting (pounds/year)

The results of the analysis indicate that the following pollution load reductions could be achieved by converting the existing dry ponds to wet ponds.

Table 4-8: Load Reductions (LR) from Retrofitting Dry Ponds				
	Lpre	**Lpost**	**LR**	**Percent LR**
Pollutant	**Pounds per year**			
TSS	1,242,298	248,460	993, 838	80%
TN	8,258	5,781	2,477	30%
TP	1,186	593	593	50%

Note that significant pollution load reductions in the runoff related to the developed land in the watershed, particularly for TSS, may be made by installing the 19,479,417 CF of WQv BMPs proposed.

2. Cost Analysis of Retrofit of the Existing SWM Ponds in the Pine Creek Watershed

An estimate of the water quality impact and cost to retrofit the existing SWM dry will be explored in this section.

Using the construction cost estimating approach provided in the CWP manual, *Urban Stormwater Retrofit Practices*, the estimated cost to address the water quality deficit can be determined. See Appendix 6 for more information.

Wet pond construction costs may be estimated from the equation by Bron and Schueler (1997) as updated to 2006 construction costs (CC). The equation is as follows for wet extended detention ponds:

$$\mathbf{CC = (12.02)(Vs^{0.750})}$$

Where
CC = Construction costs
V_S = The volume of storage in cubic feet.

The CWP manual also indicates that stormwater retrofits cost approximately 2.3 times as much as new construction due to complicated construction costs. The total estimated costs are provided in the table below.

Table 4-9: Costs to Address Water Quality Treatment BMP Needs

WQv	Retrofit Volume	Proposed New Treatment Volume	Estimated Cost of New Wet Ponds	Estimated Pond Retrofit Cost	Total Costs
(cubic feet)	(cubic feet)	(cubic feet)	($)	($)	($)
19,476,417	4,186,676	15,289,741	$ 2,939,034	$1,962,392	$4,901,426

Therefore, the total cost (in 2006 dollars) to address the water quality volume needs in the Pine Creek watershed are estimated to be approximately five million dollars ($5,000,000).

It should be noted that these estimates do not include land costs and professional fees, as theses costs are very site specific and difficult to estimate. For the purpose of this study we will assume that the land costs and professional fees and other contingencies will be fifty (50%) of the construction cost. Therefore the total to address the Water Quality Volume Treatment deficit in the watershed is estimated to be approximately seven million five hundred thousand dollars ($7,500,000).

C. Streambank Restoration

Although it has been shown in the previous section that a portion of the TSS pollutant loading may be controlled by installing WQv BMPs in the watershed, the majority of the TSS loading in the watershed is due to streambank erosion caused by the increased flow rates and volumes resulting from the addition of impervious cover in the watershed.

1. Evaluation of Benefits of Addressing Streambank Erosion

In order to estimate the length of streambank that would have to be stabilized to reduce the annual TSS loads to predevelopment levels, a method as provided in the AVGWLF User Guide[17] was used to develop a spreadsheet to determine the annual loads of TSS expected for several watershed conditions. These conditions include the natural state, existing conditions and the proposed additional streambank stabilization with the WQv BMPs in place.

Using the spreadsheet it was determined that an additional 5.30 miles of streambank in the watershed will need to be stabilized to reduce the TSS loading to the amount expected in the natural state. The total amount of TSS reduction needed is 2,900,000 pounds per year (41,700,000 – 38,800,000 = 2,900,000).

[17] Evans, Barry M., David W. Lehning, and Kenneth J. Corradini, April 2008

When the expected reduction of approximately **990, 000** pounds of TSS due to the proposed installation of WQv BMPs was also accounted for, the total additional TSS reduction needed to be achieved from additional streambank stabilization is **1,910,000** pounds per year. **It was determined that each mile of streambank stabilization reduces TSS by approximately 360,000 pounds per year. Therefore it is estimated that an additional 5.3 miles of streambank will need to be stabilized in the watershed.** A summary of the results rounded to the nearest 100,000 pounds is provided below.

Table 4-10: TSS Improvements from Stabilized Streambanks

Watershed Condition	TSS from Streambank Erosion (pounds/year)	Total Stabilized Streambank (miles)	Additional Proposed Stabilized Streambank (miles)
Natural State	38,800,000	0	-
Existing Conditions	41,700,000	4.35	-
With Additional Streambank Stabilization (includes 990,000 lbs/ year TSS reduction due to Proposed WQv BMPs)	Proposed TSS Goal 38,800,000	9.65	5.3

2. Estimated Cost of Streambank Stabilization

A study titled *Streambank Stabilization: An Economic Analysis From the Landowners' Perspective,*[18] provides construction cost information for several streambank stabilization techniques. The projects implemented in the study used bend weirs and rock veins to protect the streambank toe and riparian forest buffers established on newly constructed sloped banks and buffers. The construction costs were estimated to range from $6 to $22 per foot (2004). Due to site constraints and existing urban conditions, it is expected that other more costly approaches such as retaining walls and gabion baskets may be needed to stabilize streambanks in the Pine Creek Watershed. These types of structures are estimated to cost $250 per foot of wall (6' height). If it is assumed that 1.9 miles were stabilized using retaining structures and the remaining 3.4 miles stabilized using rock veins, toe protection, forested buffers and other less invasive approaches; and if inflation, permitting costs, legal and design fees are included, the estimated cost to stabilize streambanks in the Pine Creek Watershed is expected to cost from $85

[18] Williams, J.R., P.M. Clark, and P.G. Balch. Streambank Stabilization: An Economic Analysis from the Land owners' Perspective. *Journal of Soil and Water Conservation*, November 1, 2004 http://www.jswconline.org/content/59/6/252.abstract

to $115 per lineal foot. Therefore, the cost to improve the additional 5.3 miles of streambank is expected to cost between 2.4 and 3.2 million dollars.

D. Current or Proposed Watershed Protection and Restoration Opportunities

There are several current and proposed projects for this watershed that begin to address water quality concerns through planning and restoration.

1. Act 167 Stormwater Management Pond Evaluation

The North Hills Council of Governments (NHCOG) has coordinated an evaluation of each of the significant stormwater management ponds located within the Girtys Run, Pine Creek, Squaw Run and Deer Creek watersheds (the Act 167 Study Area).

The inspection was completed from May through August of 2008. The ponds were located using a GIS database of the significant stormwater ponds that was developed for the Act 167 project and this Watershed Implementation Plan for the Pine Creek Watershed. An inspection crew of two people visited each of the stormwater ponds (+/-179 ponds) during the inspection period. At each pond, the inspectors recorded information about the condition of each pond, preparing a dimensioned sketch of the outlet structure, photographing the facility, and recording the coordinates of the outlet structure, spillway, and discharge pipe using sub-centimeter GPS equipment. A copy of the data dictionary structure for the project is provided in Appendix 7. The inspection database developed from this project is integrated into the GIS coverage of stormwater management facilities for the study area.

An important aspect of the project is to develop a consistent watershed approach for the ongoing inspection, maintenance and improvements to the existing and proposed stormwater management infrastructure in the North Hills. The inspection findings have been reported to each of the municipalities involved in the study. It is hoped that a focus on the condition of the existing stormwater management infrastructure will result in improved maintenance and corrective actions where needed.

In addition to providing a basic inventory and inspection results for the facilities, the detailed GIS coverage will be used in the Act 167 modeling study, outlined below, to determine which facilities appear to be large enough to retrofit in order to provide increased and cost effective flood protection and water quality benefits to the watersheds.

2. Act 167 Stormwater Modeling Project

In order to further develop the sophistication and scope of the NHCOG's efforts to reduce flooding and protect waterways, the main element of the next phase will be the development of a GIS-based watershed model. This model will contain hydrologic and hydraulic (H&H) elements and will also be set up to model water quality (WQ) parameters. Such a model, once developed, will be an important tool to assess the effectiveness of our current efforts and to predict the expected results of future activities and projects.

The model will be developed using input parameters derived from a GIS database that will include an impervious cover layer developed during the previous Act 167 Update completed in April 2008. Existing GIS layers such as soil type, topography, sub-basin and watershed boundaries will also be utilized to develop the model.

Field work will be needed to confirm the dimensions of waterway obstructions such as bridge openings, culverts, etc. and to verify channel characteristics and cross-sections.

The proposed model will be used to confirm and verify the existing Act 167 Release Rate Percentage requirements in the four watersheds.

A primary use of the model will be to develop and evaluate proposed regional watershed improvement projects, such as stream restoration, flood plain restoration and protection, regional detention, removal of stream obstructions and other projects designed to reduce flooding and improve WQ.

Also, it is thought that the existing SWM infrastructure, constructed over the last twenty to twenty five years, may be under utilized. By remodeling and rehabilitating the larger SWM facilities, it may be possible to reduce flooding and improve WQ through better use of these existing facilities.

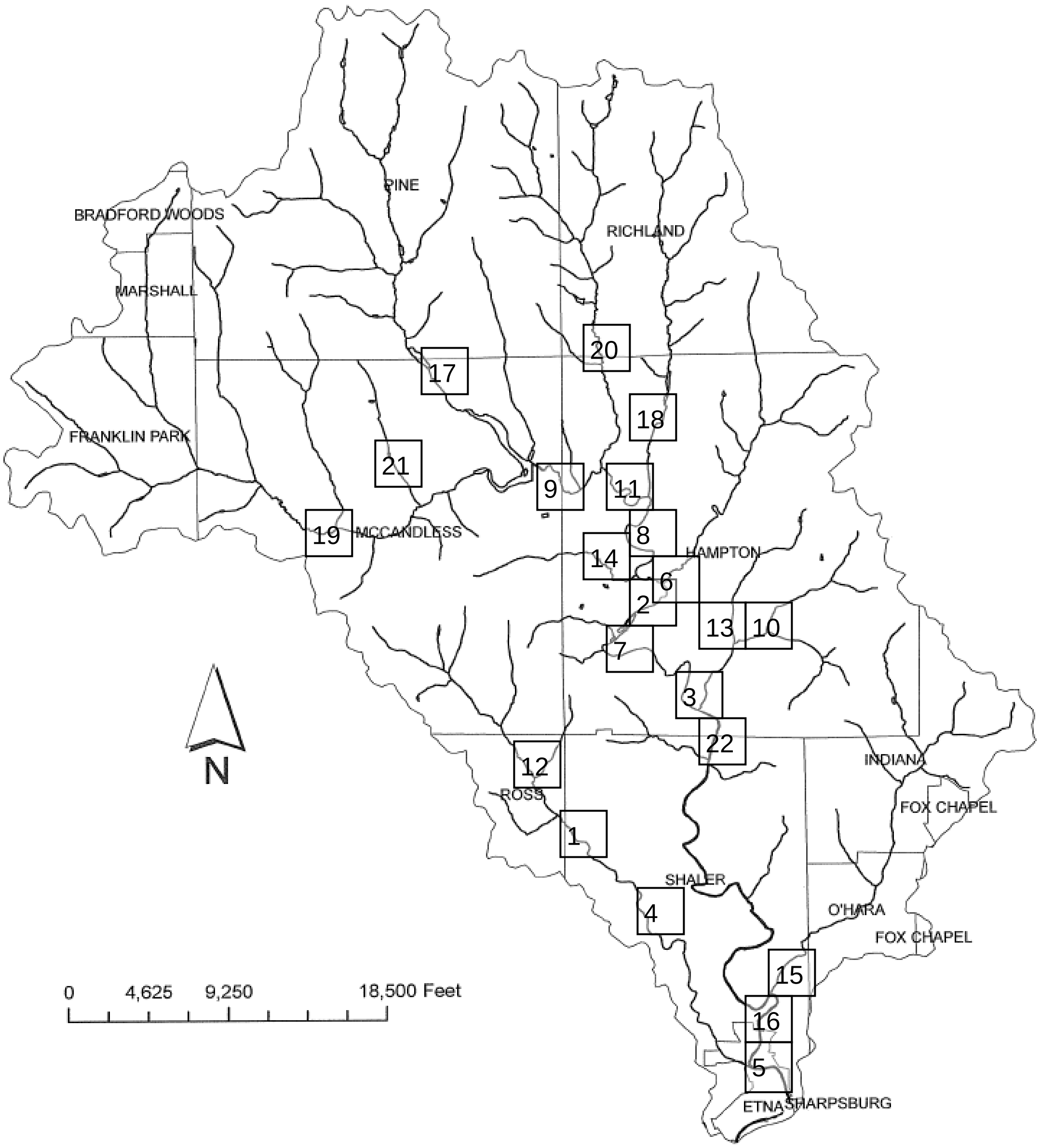
TIMELINE

- 2009 - 2011 – Prepare GIS Based Hydrologic and Hydraulics Analysis
- 2012 – Prepare stormwater management ordinance amendments

3. Proposed Stream Bank Stabilization Projects

Information summarized by Greg Holesh, DEP Watershed Manager, highlights 22 eroded stream reaches in the Pine Creek Watershed that are undergoing stabilization/restoration projects or are in need of stream restoration projects in the future. See Table 4-11 and Map 4-2 for locations. Additional data will be needed to determine how much of each segment is suitable for restoration or stabilization. The ranking of the projects is a pragmatic one based upon the judgment of the DEP's Watershed Manager. He used his local knowledge of the watershed to determine which project were most able to proceed based upon the cooperation of the local municipality, land owner(s), and the availability of potential funding.

Table 4-11: Potential Pine Creek Watershed Stream Restoration Projects			
Project Location	**Project #**	**Project Length (LF)**	**Implementation Schedule (from project approval date) Years**
West Little Pine (Fawcett Fields)	1	1,500	1-5
Pine Creek (Bryant Road – Phase II)	2	1,000	1-5
Pine Creek (at Hampton WWTP)	3	600	1-5
West Little Pine (DS of Fawcett to Wetzel)	4	1,200	1-5
Pine Creek (Municipal Park in Etna)	5	1,500	1-5
Bryant Rd. – Phase III (Upstream of Phase II)	6	1,600	1-5
Bryant Rd. – IV (Below Phase II)	7	1,200	1-5
Crouse Run (Sample to Wildwood)	8	6,500	1-5
Pine Creek Below Spillway (to McCandless WWTP)	9	2,750	6-10
Harts Run (starting at Rt. 8 upstream)	10	300	6-10
Pine Creek (Wildwood Highlands to Willow Run)	11	4,259	6-10
West Little Pine (Hodil to Vilsack – Primarily around Hodil)	12	3,200	6-10
Gourdhead Run (above Hampton Lake)	13	500	6-10
Pine Creek (parallel to Duncan crossing Mt. Royal Blvd.)	14	4,000	6-10
East Little Pine (around Kat St.)	15	300	6-10
Pine Creek (curve at Kat St.)	16	2,500	6-10
North Fork Pine Creek (along Pearce Mill Rd.)	17	750	6-10
Montour Run (segments between Rt. 910 and Wildwood)	18	1,000	11-15
Pine Creek (along Pine Creek Rd.)	19	1,000	11-15
Wexford Run (segments between Rt. 910 and Pine Creek Rd.)	20	1,200	11-15
Rineman Run (segments between Grubbs and Pine Creek Rd.)	21	600	11-15
Pine Creek (Willow to Sample)	22	1,200	11-15



Map 4-2: Potential Pine Creek Stream Restoration Projects

Through the Riparian and Stream Channel Assessment, the North Area Environmental Council is working with project partners to identify projects and facilitate the restoration projects. Two of these projects are outlined below.

West Little Pine / Fawcett Fields Restoration (Table 4-11, project #1)

Staff from Shaler Township noted that the floods from Hurricane Ivan created a severe erosion problem along West Little Pine Creek in a park named Fawcett Fields, which is owned by the township. Members of the Pine Creek Watershed Coalition reviewed the site with consultants who estimated that 550 tons of sediment had eroded from the streambanks. The local chapter of Trout Unlimited applied for and received a grant from DEP to design, permit, and construct a streambank stabilization project along 1,000 ft of West Little Pine. Matching funds and donated labor for the project are being provided by the Allegheny County Conservation District, the Township of Shaler, and the members of Trout Unlimited. The project began in 2008 and is expected to take three years to complete. Project cost is $154,475.

TIMELINE

- Spring 2008 – Grant awarded to Trout Unlimited
- Summer 2008 – Background data collected
- January 2009 – Design restoration project
- Fall 2009 – Permitting
- Spring 2010 – Construction
- Spring 2010 – Post construction Sampling

Crouse Run Restoration (Table 4-11, project #8)

A similar erosion problem was reported for a section of Crouse Run owned by the Pine Creek Land Conservation Trust, where it was estimated that 800 tons of soil have eroded from the stream banks. In 2009, DEP granted a proposal by the Pine Creek Land Conservation Trust to design a natural stream restoration project on a 2,500 foot section of Crouse Run in the Crouse Run Nature Reserve. The design and permitting costs are estimated to be $54,541. Construction costs, which were not part of the proposal that was granted, are estimated to be nearly $300,000.

TIMELINE

- Spring 2009 – Grant awarded to Pine Creek Land Conservation Trust
- August 2009 – Contract awarded and executed
- December 2009 – Initial data survey and data collection
- Spring 2010 – Design
- Summer 2010 - Permitting

4. Three Rivers Rain Garden Alliance

The Three Rivers Rain Garden Alliance is a group of environmental and gardening organizations that has come together to promote the installation of rain gardens through education and facilitation as one means of reducing stormwater impacts in Allegheny County. The Alliance hopes to develop highly visible demonstration projects and encourage homeowners to install them on their properties. Rain gardens are particularly successful at removing nutrients and solids. While it would take a significant number of properties installing rain gardens to make an impact in the water quality of local streams, the low cost and relative ease of installation coupled with the increase in education and awareness make this a good investment. The CWP Urban Subwatershed Restoration Manual estimated that the cost of installing a rain garden ranged from $4.00 per cubic foot (volunteer installation) to $7.50 per cubic foot (professional installation).

Municipalities and organizations can take part in the Rain Garden Alliance activities and promote rain gardens on private and municipally owned properties. They can take advantage of the resources and expertise of Alliance members to achieve these goals. Information about the Alliance can be found at www.raingardenalliance.org.

Although rain barrels are not part of the Alliance's focus at this time, there are successful rain barrel programs in the region. The cost of a rain barrel can range from $100 to $200, and it allows for the complete removal of pollutants from the waterway. Municipalities can encourage homeowners to install a rain barrel on their properties.

TIMELINE

- Winter 2009 – Alliance will set Rain Garden goals for 2010
- Winter 2009 - Municipalities and Coalition will contact Alliance to organize educational efforts in watershed.
- Spring 2010 - Municipalities and Coalition will explore the creation of a rain barrel program for the watershed

5. Pine Creek Watershed Conservation Plan

The North Area Environmental Council received a grant from the PA Department of Conservation and Natural Resources (DCNR) to complete a Watershed Conservation Plan for the entire Pine Creek Watershed. This document will summarize existing information about the natural, cultural, and recreation resources of the watershed, gather public input about their visions for the watershed and its current needs, and develop a list of projects or strategies that will enhance, restore, or conserve those resources. Public input plays a major role in the development of this Plan. Projects listed in an approved Conservation Plan are eligible to apply for implementation funds from DCNR.

TIMELINE

- Jan. 2009 – Begin Plan
- Spring 2009 – Public meetings
- Winter 2009 – Public meetings
- Spring 2010 – Final Plan

6. North Park Lake Aquatic Ecosystem Restoration Project

North Park is Allegheny County's largest park. Its main attraction is North Park Lake, a man made lake created by the impoundment of Pine Creek that provides fishing and boating opportunities to visitors. When the lake was created in 1935, it had a surface area of 75 acres and a depth of 24 feet. Sedimentation from upstream development has reduced its surface area to approximately 60 acres and cut its depth in half. The drainage basin contributing to the lake is 25 square miles.

The U.S. Corps of Engineers and Allegheny County have developed a project to restore the lake. Phase 1 of the North Park Lake Aquatic Ecosystem Restoration Project will restore 33 acres of the lake by dredging the sediment and removing it to an offsite location. Phase 1 will cost $8 million and will be funded by a grant from the Corps of Engineers and by Allegheny County. It is expected to last for two years. This phase will restore at least 8,000,000 cubic feet of water quality volume to the watershed. The details for Phase 2 are not available, but it is expected to address the remaining 42 acres of the lake.

Additionally, mitigation projects by the Pennsylvania Turnpike are being planned that will create two additional wetlands near the lake.

TIMELINE
- Spring 2009 – Phase 1 dredging
- Spring 2011 – Phase 2 ends

7. Lower Allison Park Flood Control Project

The Township of Hampton is investigating various projects to aid downstream municipalities with regard to flood protection in the Pine Creek Watershed. In the Lower Allison Park area, basically the area in and around Route 8, Duncan Avenue, Pine Creek, and Gourdhead Run, the Township has proactively acquired numerous flood prone properties. The Township has hired several consultants to look at the feasibility of constructing regional stormwater facilities in the Lower Allison Park area.

Two on-stream stormwater management facilities were conceptually designed. The first, a permanent lake on Pine Creek has a stormwater capacity of approximately 4,000,000 cubic feet. This is above a 4 foot deep permanent pool over the entire lake. The lake is approximately 8 acre in size at its normal pool elevation. Approximately 2,000 feet of Pine Creek will be inundated by the construction of the lake. The lake will also have a forebay upstream designed to collect debris before entering the lake. The lake itself will provide a debris collection value which will greatly help downstream flooding. The consulting engineering company for the project, PVE, has indicated that the proposed permanent pool (wet storage) of the Pine Creek Lake will be approximately 890,000 cubic feet.

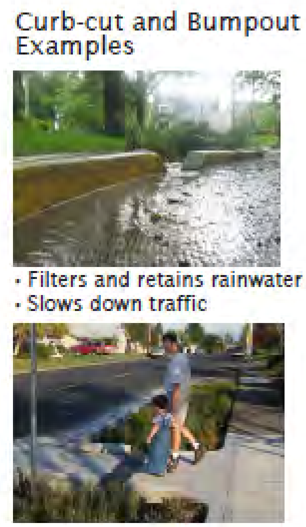
The second stormwater facility is a dry detention basin on Gourdhead Run upstream of Duncan Avenue. This basin is to be constructed in conjunction with a new Duncan Avenue Culvert which is presently undersized. The new detention basin is approximately 2.5 acres in size and will provide 7.5 million gallons of stormwater storage. The detention basin will affect about 600 feet of Gourdhead Run. The stream is proposed to be relocated and the riparian buffer will be significantly upgraded as the stream is currently bounded by walls. No wet storage is proposed for the Duncan Avenue facility.

Early estimates for the project cost are $10 million dollars. The project is not expected to be completed until 2019.

TIMELINE
- TBD

8. Etna Borough's Green Streets Program

The Borough of Etna is seeking funding to reconstruct borough streetscapes to remove stormwater from their combined sewer system, reduce stormwater runoff, and improve the appeal of the existing streetscape. The project proposes to remove 1,746 square yards of concrete curb sidewalk and 1,484 square yards of brick sidewalk and replace them with 25,940 square feet of permeable pavers and 1,891 lineal feet of concrete curb, gravel retention, and 49 rain gardens. More than 181,201 square feet of roof area will be separated from the combined sewer system and routed into detention areas. Two public parking lots will be reconstructed with permeable paving parking areas, gravel retention, and rain gardens for a total of 8,700 square feet of pervious area. The cost of construction only is more than one million dollars.



TIMELINE
• 2009 - Proposal submitted to PENNVEST • April 2010 - Grants to be announced • Project completed in 3-6 months if funding is secured

E. Steep Slope Protection and Land Conservation

One of the best ways to reduce the further impacts of development in the watershed is by the protection of existing undisturbed natural areas and of the wooded steep slopes. Wooded areas and steep wooded slopes provide substantial benefits to the watershed. Wooded and natural areas reduce pollutant loading, slow runoff, and reduce the frequency of flooding in the watershed. The process of transpiration insures a substantial volume of rainfall never runs off the surface of the land, but rather moves back into the atmosphere via plant respiration. Wooded areas along streams also provide shade and lower the water temperature in the stream. Most importantly, wooded areas and hillsides add greatly to the beauty of our region.

1. Steep Slope Protection Ordinances

A summary of the steep slope protection ordinance data gathered by the Act 167 Stormwater Management Ordinance Update is provided below. Although a few of the municipalities in the watershed have adequate steep slope protections, it should be noted that most do not. It is recommended that each of the municipalities in the watershed adopt or strengthen their existing steep slope ordinance.

Grading and Steep Slope Protection Ordinance Requirements						
Number	**Municipality**	**Separate Grading Ordinance (Number and Date)**	**Other Location of Grading Regulations (Ord. Name & Date)**	**Are There Steep Slope Restrictions?**	**Description of Steep Slope Restrictions**	**Limiting Slope Where Development is not Permitted?**
2	Bradford Woods Boro.	249 (06/74)	--			
3	Etna Boro.	--	--	1111-4.02.A.(4)	3H:1V pond side slopes, 2H:1V flood prone areas Ord. 1111-4.02.A.(4)	--
4	Fox Chapel Boro.	--	455-123 (08/85)			
5	Franklin Park Boro.	--	435-96-184-31 (11/96)			
7	Hampton Twp.	584 (02/00)	--	584-32.5 and 584-11	Slopes > 25% shall not be graded	
9	Indiana Twp.	229 (07/87)	--			
10	Marshall Twp.	101 Ch 88 (10/74)	--			
11	McCandless Twp.	625 (04/73) 519-1705 (03/69)	--			
17	O'Hara Township					
	Pine Township					
18	Richland Twp.	76 (11/72)	--	--	--	--
19	Ross Twp.	Ch. 22-Grading and Ch. 9 - Excav (10/98)	--	2035-1401(6) and Ch 22-602(5) and Ch 22-Grading and Excav (Ch 9-110(6))	12-14.9% - 40% area may be disturbed (30% in landslide prone area) 15-25% - 30% area may be disturbed (20% in landslide prone area) 25% & Above - 15% area may be disturbed (4% in landslide prone area)	--
20	Shaler Twp.	1813 (04/03)	--	1650-225-132(D)(1)(C)	Slope of 25% or more - no units permitted Slope of 15% to 25% - Max total disturbance shall not exceed 5% of the total area	25%
21	Sharpsburg Boro.	--	488 (07/91)	--	--	--

Footnotes

-- = Item not addressed in ordinances

Highlighted cells = information not found in stormwater and grading ordinances, or ordinance not provided.

2. Conservation Easements & Land Conservation

A conservation easement is a legal agreement between a landowner and an eligible organization that restricts future activities on the land to protect its conservation values. It is either voluntarily sold or donated by the landowner. Across America, thousands of landowners who care about their land have partnered with easement holders—nonprofit organizations and public agencies—to ensure the land is protected in perpetuity.[19] Easements are a good way to protect important features in a landscape like steep slopes.

The Allegheny Land Trust and the Pine Creek Land Conservation Trust are local nonprofit organizations that can assist property owners who are interested is developing a conservation easement for their property.

In 2009, the Allegheny Land Trust purchased 73 acres of wooded land adjacent to North Park. The property includes a small tributary to Pine Creek, Irwin Run, and densely wooded slopes and wetlands that trap sediment before it reaches the lake. It is estimated that this land will hold back 60 million gallons of rainwater each year.

F. Potential Funding Sources

The following funding sources are available to projects related to stream or water quality improvement projects:

Natural Resources Conservation Service

- Wildlife Habitat Incentives Program (WHIP) (www.nrcs.usda.gov/programs/whip/): a cost-share program that provides technical and financial assistance to private landowners for the development of upland, wetland, aquatic, and other types of wildlife habitat.

- Conservation Reserve Enhancement Program (CREP) (www.creppa.org): a cost share program that rewards landowners for installing conservation practices on their lands. The Conservation Practice 22 (CP 22) is designed to reestablish forested buffers along streams.

PA Department of Environmental Protection (www.dep.state.pa.us)

- Nonpoint Source Implementation Program: for 319 projects that address runoff, natural stream channel design, and streambank stabilization.

- Growing Greener Watershed Grants: watershed and stream restoration projects.

- Grants for the Enactment and Implementation of Stormwater Ordinances: designated for Act 167 communities to complete ordinance work.

[19] Byers, Elizabeth and Karen Marchetti Ponte, The Conservation Easement Handbook (Second Edition), 2005. Land Trust Alliance and Trust for Public Land, Washington D.C.

- Environmental Education: environmental literacy projects.

PA Department of Conservation and Natural Resources (www.dcnr.state.pa.us)

- Community Recreation Projects: covers land acquisition for conservation purposes
- Land Trust Projects: covers land acquisition for conservation purposes

PENNVEST (www.portal.state.pa.us)

- Offers primarily low interest loans to pay for costs associated with design, engineering, and construction of nonpoint source pollution mitigation and municipal stormwater projects.

Foundation for Pennsylvania Watersheds (www.pennsylvaniawatersheds.org)

- Grants are used for the protection, preservation, and restoration of Pennsylvania's Water resources. Program areas include: nonpoint source pollution, riparian buffer zones, watershed preservation and design, and land protection and acquisition.

Heinz Endowments (www.heinz.org)

- The Environment Program looks for programs and initiatives that will help repair the damaged caused by unsustainable practices.

Richard King Mellon Foundation (www.foundationcenter.org/grantmaker/rkmellon/)

- Program interests include watershed restoration and protection with an emphasis on western Pennsylvania.

Allegheny County Conservation District (accd.pghfree.net)

- Funds projects to remedy erosion problems and reduce sedimentation.

Other funding opportunities are listed on the website of the Pennsylvania Organization for Watersheds and Rivers (www.pawatersheds.org) and on the EPA's website (www.epa.gov/owow/funding.html).

Additionally, local organizations, civic groups, and sportsmen's groups may offer small grants or donated services for small projects. Municipalities may offer staff time and equipment as donated services.

Chapter 5: Public Participation

A. Pine Creek Watershed Coalition

The Pine Creek Watershed Coalition (Coalition) is a group of stakeholders committed to improving the health of the Pine Creek watershed. Coalition participants include members of environmental organizations, sportsmen's groups, businesses, elected officials, municipal staff, and volunteers. Active organizations in the Coalition include: the North Area Environmental Council, Allison Park Sportsmen's Club, Trout Unlimited, Pennsylvania Environmental Council, and 3 Rivers Wet Weather.

The objectives of the Coalition are to:

- Monitor the physical, chemical, and biological conditions of the watershed
- Promote environmentally and economically sound land use
- Educate watershed residents about the importance of a healthy Pine Creek.

The Coalition is chaired by the North Area Environmental Council (NAEC). NAEC has worked to protect and improve the Pine Creek watershed for more than 30 years. Currently, it manages several projects, including the Riparian and Stream Channel Assessment and the Department of Conservation and Natural Resources' Watershed Conservation Plan. NAEC also coordinates all of the volunteer monitoring efforts underway.

NAEC has been exploring opportunities to advance the objectives of the Coalition through partnership and potential staffing. It is expected that the Coalition will grow in the next few years and take the leadership role in education and watershed improvement projects.

1. Monitoring

The Coalition is in the process of reevaluating its monitoring program. Currently, NAEC manages a corps of about 20 volunteer monitors who are trained to conduct chemical and biological sampling. The Coalition has recently formed a relationship with Duquesne University, whereby graduate students from an Environmental Science and Management class and undergraduates from the Ecology Club will be able to offer monitoring assistance where needed. Plans are underway to gather voucher macroinvertebrate specimens so that more sophisticated analyses can be run on the data.

Macroinvertebrate sampling is conducted twice per year and chemical sampling is conducted a minimum of four times per year and a maximum of 12 times per year at 16 locations in the watershed. Volunteers use protocols outlined in the PA Senior Environmental Corps Water Quality Training Manual.

In 2009, the Pennsylvania Environmental Council submitted an application on behalf of the Coalition to the Consortium for Scientific Assistance to Watersheds (C-SAW) for technical assistance in redesigning the monitoring program. Coalition members have met with staff from U.S. Geological Survey (USGS) and the Alliance for Aquatic Resource Monitoring (ALLARM) to discuss next steps in a new monitoring plan. The Coalition hopes to add additional parameters like bank pins and stream profiles to measure sedimentation, as well as refine the frequency of monitoring other parameters to better achieve the group's goals. The Coalition will work with USGS and ALLARM throughout the next year to develop a new study design.

2. Outreach

The Coalition has managed several outreach projects including the publication and distribution of a Resident's Guide to Protecting Water Quality. These booklets were available for distribution at municipal offices and local libraries. The Coalition designed and developed a display on riparian buffers that was transported to different libraries in the watershed and hosted public and municipal programs by the Stroud Water Research Center.

The Coalition and NAEC will continue with public education and outreach as the Watershed Implementation Plan moves forward. The Coalition has a new webpage (www.pinecreekwpa.org), which houses several reference documents that are available for downloading. The webpage will be used to update the communities about potential watershed projects and offer suggestions for how residents can become involved. Additional web-based resources will be developed during the Watershed Conservation Plan that is underway. The Watershed Conservation Plan relies on an intensive public participation component, and the Coalition hopes to maintain the public interest in developing additional watershed projects.

NAEC produces a newsletter for its membership and consistently reports on the successes of the Coalition. NAEC also maintains media contacts and has been successful in getting media attention for Pine Creek projects.

3. Evaluation

The Coalition meets at least eight times per year and is well suited to manage and track the progress of the Watershed Implementation Plan. Members have shared the task of tackling new projects by alternating responsibility for each project. The groups have good working relationships with local municipalities who also participate in the North Hills Council of Governments.

During the next year, the Coalition is planning to undergo strategic planning to strengthen its capacity to manage and monitor a large number of projects. With this in mind, the Coalition will be the lead organization to revisit the Implementation Plan and the monitoring data on a biennial basis to gauge the progress of the projects.

Considering the large scale restoration needed to counter the widespread impacts from stormwater, it is likely that it will take a considerable amount of time to evaluate the Plan's effectiveness. However, if long term data trends fail to show any water quality improvements, the models will be revisited and additional remedial actions will be prescribed.

B. North Hills Council of Governments

The North Hills Council of Governments (NHCOG) is a voluntary coalition of twenty municipalities, in both Allegheny and Butler Counties. It has taken the lead in organizing and managing the Act 167 Plan for the communities within the Pine Creek, Girty's Run, Squaw Run, and Deer Creek Watersheds. Currently, there is no authority that has the responsibility to manage existing or proposed stormwater BMPs in the watershed. However, the communities in the NHCOG have been moving toward regional water quality and flood control. It is hoped that the Act 167 process will lead to a more comprehensive watershed based management of stormwater projects. Therefore, the NHCOG will have primary responsibility for prioritizing, evaluating, and managing projects related to SWM ponds, ordinance revisions, and flood plain restoration and protection. Information about the Act 167 can be viewed and downloaded from the Ross Township website (www.ross.pa.us).

C. Residents

The residents of the Pine Creek watershed have shown considerable interest in this watershed. They have volunteered their time to monitor its health, attended public meetings for proposed projects, and contacted members from the Coalition about their concerns. It is expected that there will be public interest in the Implementation Plan and that the public will follow its progress.

Chapter 6: Conclusions and Implementation Schedule

Analyses of the modeling indicate two primary means for improving water quality in the Pine Creek watershed: increasing water quality volume (WQv) as wet ponds and restoring degraded streambanks. The total WQv needed is 19,479,417 cubic feet. Some of this storage can be gained by retrofitting existing dry detention ponds, but the majority will be formed by new storage detention. Constructions costs, in 2006 dollars, are estimated to be nearly $5 million, or $7.5 million if land costs and professional fees are included. The analysis also determined that 5.3 miles of restored streambank is necessary for water quality improvements. The cost of restoring the streambank is estimated to be between $2.4 and 3.2 million dollars.

While this report emphasizes the two aforementioned methods for improving water quality, other options like rain gardens, rain barrels, porous pavements, land preservation, Green Streets programs, etc., should be considered where possible.

A schedule for BMP implementation appears below. Projects are generally prioritized based upon active groups in the area, other active projects, ease of access and potential to get funding. As a result, BMP implementation should be considered an adaptive process, so projects may be adjusted accordingly as circumstances and opportunities arise.

Table 6-1: BMP Implementation Schedule

Schedule (from date of plan approval)	**Implementation Activity**	**Subwatersheds**	**Milestone**
Years 1-5	Restore 4 miles of stream bank	• West Little Pine Creek • Crouse Run	Measurable reduction of TSS at restoration sites of 1,440,000 pounds of TSS annually
	Revise monitoring program with C-SAW program	Entire Basin	Adoption of final study design
	Use Act 167 Planning Process to identify locations and costs of WQv BMPs retrofits and additions	Entire Basin	Completion of Act 167 Modeling Study
	North Park Lake Ecosystem Restoration Project	Main stem of Pine Creek (Subwatershed 3)	Restoration of +/- 8,000,000 cu ft of storage. Measurable reduction of 400,000 lbs TSS, 1000 lbs TN, & 60 lbs TP annually

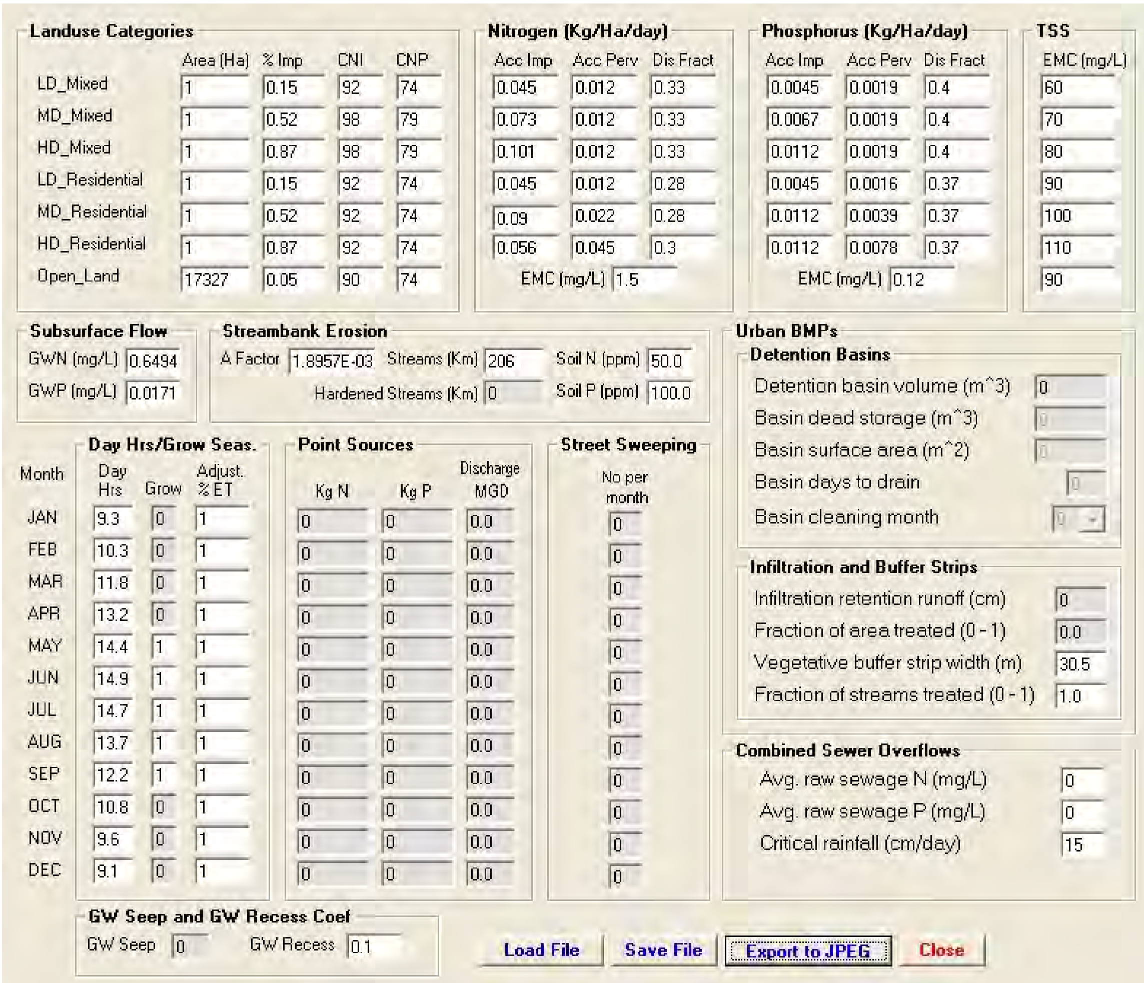
	Etna Green Streets Program	Main stem of Pine Creek (Subwatershed 1)	Removal of stormwater from combined system
Years 6-10	Restore 2 miles of stream bank	Entire Basin	Measurable reduction of TSS at restoration sites of 720,000 pounds of TSS annually
	Increase wet storage by 4,000,000 cu ft.	Entire Basin below North Park Lake	Measurable reduction of 200,000 lbs TSS, 500 lbs TN, & 30 lbs TP annually
Years 11-15	Increase wet storage by 4,000,000 cu ft.	Entire Basin below North Park Lake	Measurable reduction of 200,000 lbs TSS, 500 lbs TN, & 30 lbs TP annually
Years 16 - 20	Increase wet storage by 4,000,000 cu ft.	Entire Basin below North Park Lake	Measurable reduction of 200,000 lbs TSS, 500 lbs TN, & 30 lbs TP annually
	Lower Allison Park Flood Control Project. (Includes the addition of 890,000 cu ft. of WQv)	Main stem of Pine (Subwatershed 3) and Gourdhead Run	Measurable reduction of 44,500 lbs TSS, 111 lbs TN, & 7 lbs TP annually
Years 1-20	Look for and implement additional structural and nonstructural BMPs and Green Streets projects (e.g. rain gardens, rain barrels, porous pavements, etc.)	Entire Basin	‘Greener’ Communities

Appendix 1 - Modeling Results: Natural Conditions, Entire Basin

Modeling Results

Natural Conditions

The Entire Pine Creek Watershed



Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	1	0.15	92	74
MD_Mixed	1	0.52	98	79
HD_Mixed	1	0.87	98	79
LD_Residential	1	0.15	92	74
MD_Residential	1	0.52	92	74
HD_Residential	1	0.87	92	74
Open_Land	17327	0.05	90	74

Nitrogen (Kg/Ha/day) / **Phosphorus (Kg/Ha/day)** / **TSS**

N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
0.045	0.012	0.33	0.0045	0.0019	0.4	60
0.073	0.012	0.33	0.0067	0.0019	0.4	70
0.101	0.012	0.33	0.0112	0.0019	0.4	80
0.045	0.012	0.28	0.0045	0.0016	0.37	90
0.09	0.022	0.28	0.0112	0.0039	0.37	100
0.056	0.045	0.3	0.0112	0.0078	0.37	110
EMC (mg/L) 1.5			EMC (mg/L) 0.12			90

Subsurface Flow
GWN (mg/L) 0.6494
GWP (mg/L) 0.0171

Streambank Erosion
A Factor 1.8957E-03 Streams (Km) 206 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / **Point Sources** / **Street Sweeping**

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	0	0	0.0	0
FEB	10.3	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	0
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	0
JUL	14.7	1	1	0	0	0.0	0
AUG	13.7	1	1	0	0	0.0	0
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins
Detention basin volume (m^3) 0
Basin dead storage (m^3) 0
Basin surface area (m^2) 0
Basin days to drain 0
Basin cleaning month 0

Infiltration and Buffer Strips
Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 1.0

Combined Sewer Overflows
Avg. raw sewage N (mg/L) 0
Avg. raw sewage P (mg/L) 0
Critical rainfall (cm/day) 15

GW Seep and GW Recess Coef
GW Seep 0 GW Recess 0.1

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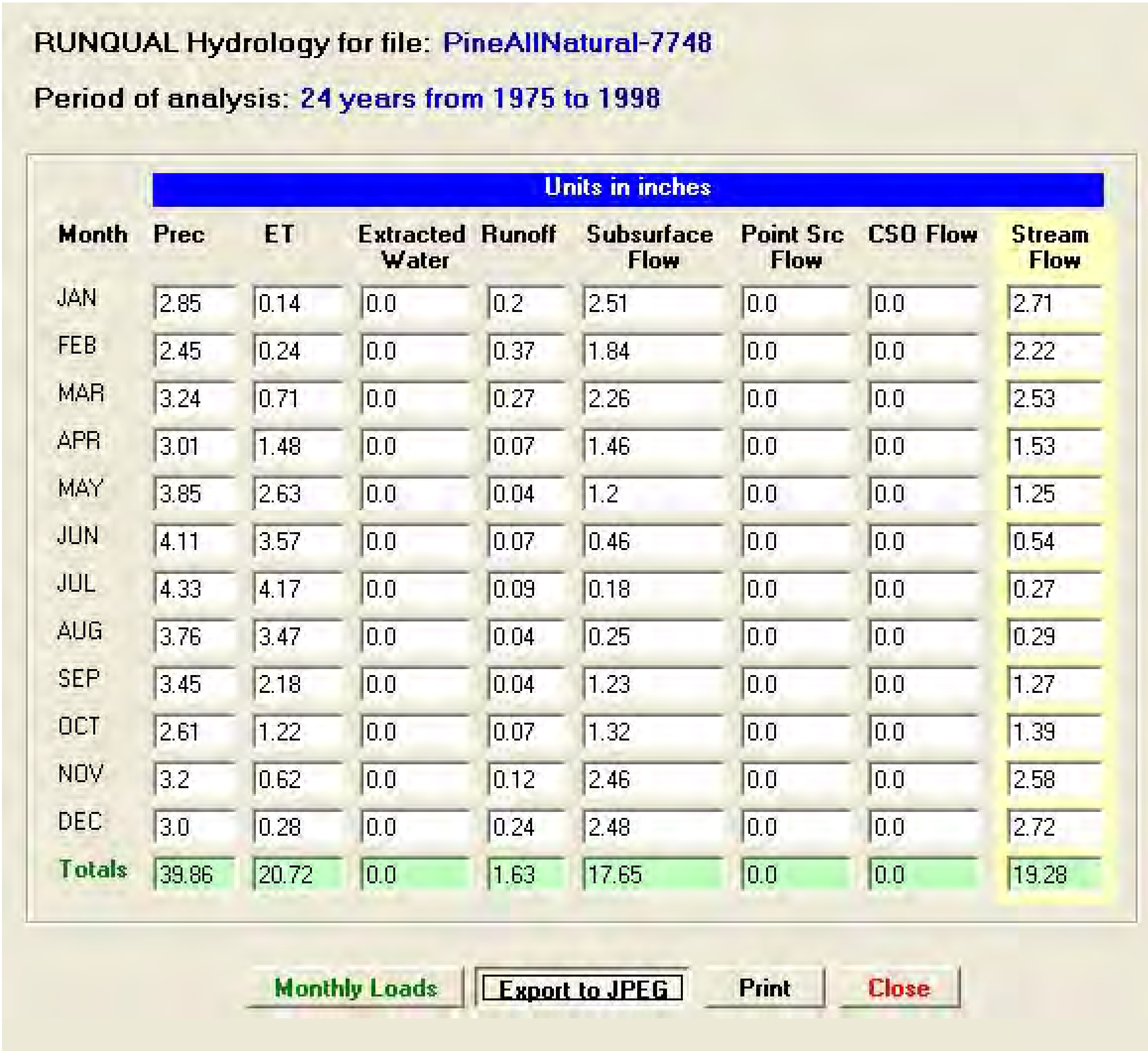
RUNQUAL Data Input – Pine All - Natural Conditions


RUNQUAL Hydrology for file: PineAllNatural-7748

Period of analysis: 24 years from 1975 to 1998

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
	Units in inches							
JAN	2.85	0.14	0.0	0.2	2.51	0.0	0.0	2.71
FEB	2.45	0.24	0.0	0.37	1.84	0.0	0.0	2.22
MAR	3.24	0.71	0.0	0.27	2.26	0.0	0.0	2.53
APR	3.01	1.48	0.0	0.07	1.46	0.0	0.0	1.53
MAY	3.85	2.63	0.0	0.04	1.2	0.0	0.0	1.25
JUN	4.11	3.57	0.0	0.07	0.46	0.0	0.0	0.54
JUL	4.33	4.17	0.0	0.09	0.18	0.0	0.0	0.27
AUG	3.76	3.47	0.0	0.04	0.25	0.0	0.0	0.29
SEP	3.45	2.18	0.0	0.04	1.23	0.0	0.0	1.27
OCT	2.61	1.22	0.0	0.07	1.32	0.0	0.0	1.39
NOV	3.2	0.62	0.0	0.12	2.46	0.0	0.0	2.58
DEC	3.0	0.28	0.0	0.24	2.48	0.0	0.0	2.72
Totals	39.86	20.72	0.0	1.63	17.65	0.0	0.0	19.28

Hydrologic and Hydraulic Results – Pine Watershed – Natural Conditions

RUNQUAL Average Monthly Loads for file: PineAllNatural-7748

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	4803732	15790	18969	416	1114
FEB	4654088	11617	17251	306	1172
MAR	4625390	14341	18446	378	1131
APR	3293870	9203	10379	242	647
MAY	2531711	8365	9133	220	521
JUN	2073975	5850	6974	154	437
JUL	1636625	4491	5672	118	364
AUG	1620526	4596	5224	121	323
SEP	2781334	8712	9388	229	547
OCT	3082573	8842	9927	233	610
NOV	4584482	15486	17446	408	995
DEC	4871912	15616	19375	411	1159
Totals	40560219	122909	148183	3237	9021

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine Watershed – Natural Conditions

RUNQUAL Hydrology for file: pallwonp-7748

Period of analysis: 24 years from 1975 to 1998

RUNQUAL Hydrology for file: PineAllNatural-7748

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	2	2.4	77	2929.1	2929.1	74.0	74.0
MD_Mixed	2	12.8	480	2376.0	2376.0	60.0	60.0
HD_Mixed	2	19.9	855	643.5	643.5	16.3	16.3
LD_Residential	2	2.4	116	2485.3	2614.2	57.6	57.6
MD_Residential	2	5.1	271	2573.0	2706.4	79.3	79.3
HD_Residential	2	7.6	446	1527.2	1527.2	43.0	43.0
Open_Land	42816	1.6	1421275		23722.3		1897.8
Subsurface				110374.7	110374.7	2906.4	2906.4
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			39136699		1956.8		3913.7
Totals	42831	1.6	40560219	122909	148850	3237	9048

Monthly Loads | Export to JPEG | Print | Close

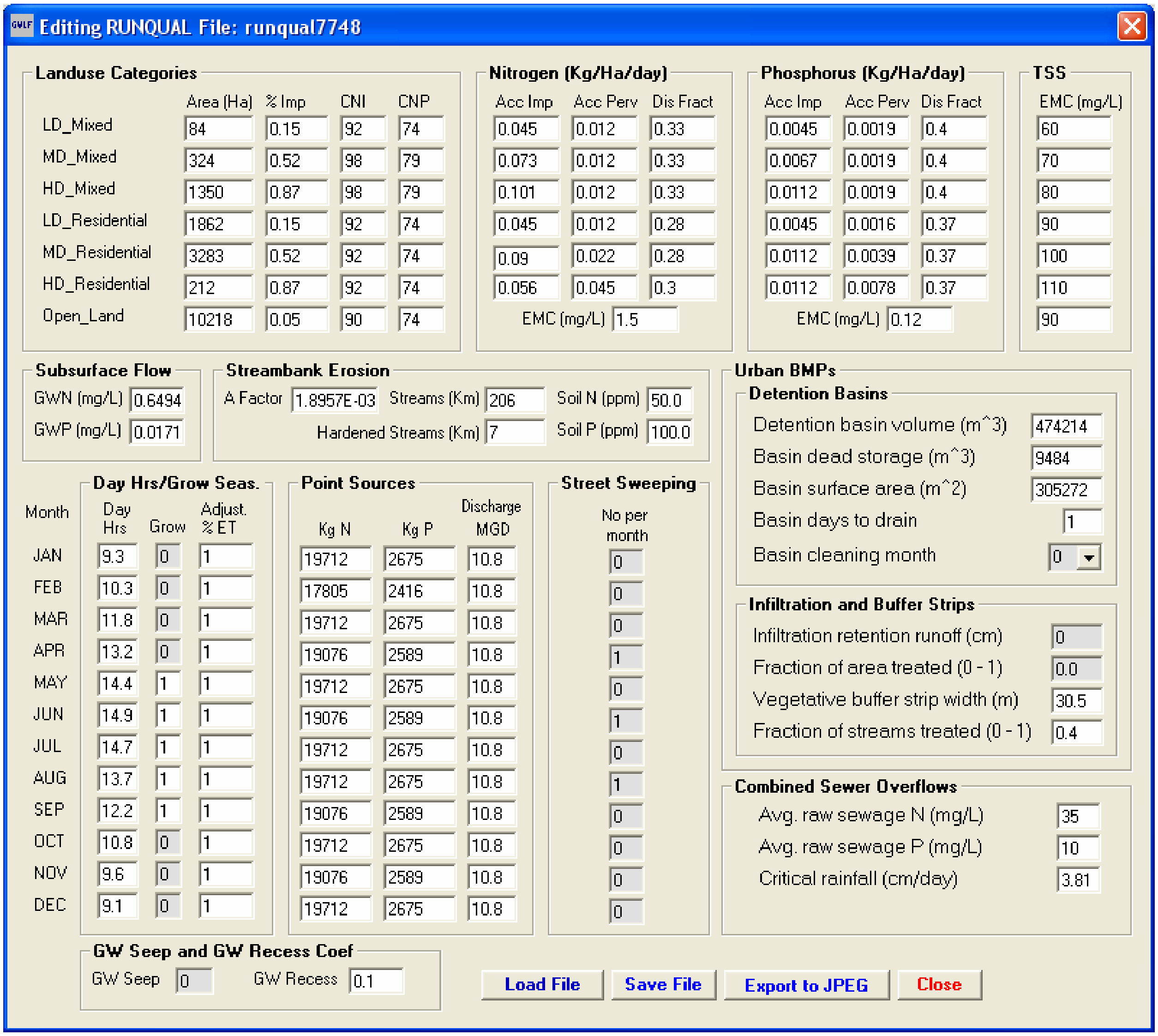
Pollution Loading by Source – Pine Watershed – Natural Conditions

Appendix 2 - Modeling Results: Existing Conditions, Entire Basin

Modeling Results

Existing Conditions

The Entire Pine Creek Watershed



Editing RUNQUAL File: runqual7748

Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	84	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	324	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	1350	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	1862	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	3283	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	212	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	10218	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5 — Phosphorus EMC (mg/L) 0.12

Subsurface Flow: GWN (mg/L) 0.6494; GWP (mg/L) 0.0171

Streambank Erosion: A Factor 1.8957E-03; Streams (Km) 206; Soil N (ppm) 50.0; Hardened Streams (Km) 7; Soil P (ppm) 100.0

Urban BMPs

Detention Basins
- Detention basin volume (m^3) 474214
- Basin dead storage (m^3) 9484
- Basin surface area (m^2) 305272
- Basin days to drain 1
- Basin cleaning month 0

Infiltration and Buffer Strips
- Infiltration retention runoff (cm) 0
- Fraction of area treated (0 - 1) 0.0
- Vegetative buffer strip width (m) 30.5
- Fraction of streams treated (0 - 1) 0.4

Combined Sewer Overflows
- Avg. raw sewage N (mg/L) 35
- Avg. raw sewage P (mg/L) 10
- Critical rainfall (cm/day) 3.81

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	19712	2675	10.8	0
FEB	10.3	0	1	17805	2416	10.8	0
MAR	11.8	0	1	19712	2675	10.8	0
APR	13.2	0	1	19076	2589	10.8	1
MAY	14.4	1	1	19712	2675	10.8	0
JUN	14.9	1	1	19076	2589	10.8	1
JUL	14.7	1	1	19712	2675	10.8	0
AUG	13.7	1	1	19712	2675	10.8	1
SEP	12.2	1	1	19076	2589	10.8	0
OCT	10.8	0	1	19712	2675	10.8	0
NOV	9.6	0	1	19076	2589	10.8	0
DEC	9.1	0	1	19712	2675	10.8	0

GW Seep and GW Recess Coef: GW Seep 0; GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input – Pine All - Existing Conditions

RUNQUAL Hydrology for file: pallwonp-7748

Period of analysis: 24 years from 1975 to 1998

Month	Units in inches							
	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.85	0.14	0.0	0.42	2.29	0.29	0.021	2.99
FEB	2.45	0.24	0.0	0.68	1.54	0.26	0.011	2.47
MAR	3.24	0.71	0.0	0.57	1.96	0.29	0.028	2.81
APR	3.01	1.48	0.0	0.25	1.28	0.28	0.003	1.81
MAY	3.85	2.63	0.0	0.21	1.04	0.29	0.011	1.54
JUN	4.11	3.57	0.0	0.28	0.26	0.28	0.021	0.82
JUL	4.33	4.17	0.0	0.33	0.09	0.29	0.0	0.7
AUG	3.76	3.45	0.0	0.22	0.1	0.29	0.029	0.6
SEP	3.45	2.18	0.0	0.2	1.07	0.28	0.003	1.55
OCT	2.61	1.22	0.0	0.2	1.19	0.29	0.008	1.67
NOV	3.2	0.62	0.0	0.31	2.26	0.28	0.0	2.85
DEC	3.0	0.28	0.0	0.45	2.27	0.29	0.026	3.01
Totals	39.86	20.7	0.0	4.1	15.36	3.37	0.161	22.84

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine Watershed – Existing Conditions

RUNQUAL Average Monthly Loads for file: pallwonp-7748

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	4984767	55105	58907	5943	6706
FEB	4844246	49320	55344	5668	6582
MAR	4835567	54237	59351	6069	6914
APR	3656358	49697	52013	5872	6396
MAY	2850031	48310	50248	5878	6297
JUN	2385168	40787	43274	5395	5810
JUL	1928162	42454	45368	5882	6284
AUG	1979770	42509	44488	5753	6090
SEP	3132731	48416	50307	5843	6285
OCT	3362487	49923	51777	5969	6431
NOV	4802674	56395	59308	6098	6777
DEC	5027752	56690	60768	6181	6968
Totals	43789714	593842	631153	70550	77539

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine Watershed – Existing Conditions

RUNQUAL Hydrology for file: pallwonp-7748

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	208	2.4	3200	130.7	130.7	17.2	17.2
MD_Mixed	801	12.8	76803	408.8	408.8	53.9	53.9
HD_Mixed	3336	19.9	570457	461.3	461.3	60.9	60.9
LD_Residential	4601	2.4	106416	2457.3	2507.7	297.7	300.2
MD_Residential	8112	5.1	438780	4485.6	4577.6	722.4	728.5
HD_Residential	524	7.6	46642	171.9	171.9	25.3	25.5
Open_Land	25249	1.6	838148		35225.1		2818.0
Subsurface				94941.1	94941.1	2500.0	2500.0
Point Sources				488989.9	488989.9	66360.2	66360.2
CSOs				1795.3	1795.3	512.9	512.9
Streambank			41709267		2085.5		4170.9
Totals	42831	4.1	43789714	593842	631295	70550	77548

Monthly Loads | Export to JPEG | Print | Close

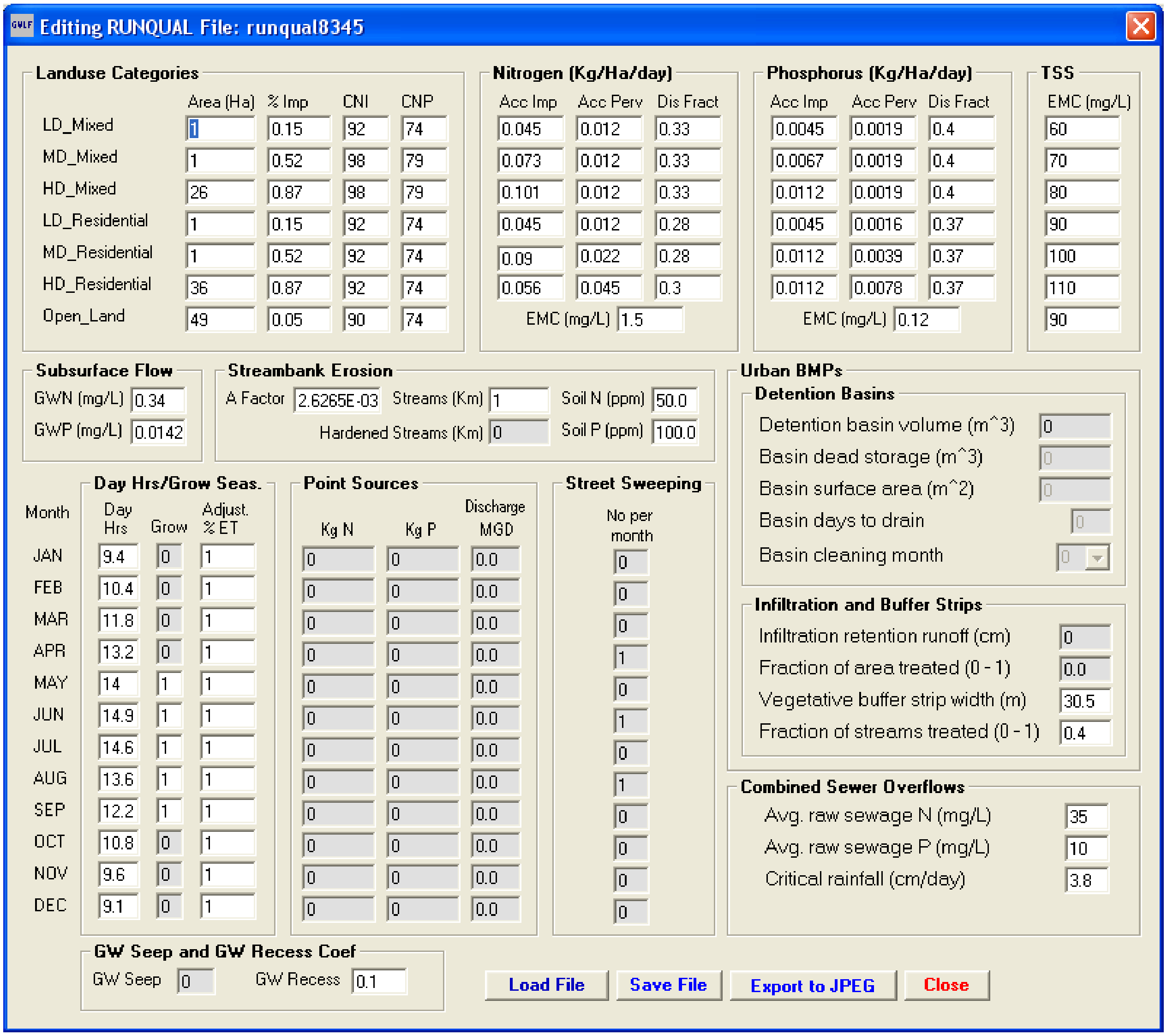
Pollution Loading by Source – Pine Watershed – Existing Conditions

Appendix 3 - Modeling Results: Existing Conditions, Sub-basins

Modeling Results

Existing Conditions

Subbasin: Pine 1



Editing RUNQUAL File: runqual8345

Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	1	0.15	92	74
MD_Mixed	1	0.52	98	79
HD_Mixed	26	0.87	98	79
LD_Residential	1	0.15	92	74
MD_Residential	1	0.52	92	74
HD_Residential	36	0.87	92	74
Open_Land	49	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0.101	0.012	0.33
0.045	0.012	0.28
0.09	0.022	0.28
0.056	0.045	0.3

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.0045	0.0019	0.4
0.0067	0.0019	0.4
0.0112	0.0019	0.4
0.0045	0.0016	0.37
0.0112	0.0039	0.37
0.0112	0.0078	0.37

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
80
90
100
110
90

Subsurface Flow

GWN (mg/L) 0.34
GWP (mg/L) 0.0142

Streambank Erosion

A Factor 2.6265E-03 Streams (Km) 1 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 0
Basin dead storage (m^3) 0
Basin surface area (m^2) 0
Basin days to drain 0
Basin cleaning month 0

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.4

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 0.1

Load File Save File Export to JPEG Close

RUNQUAL Data Input – Pine 1 - Existing Conditions

RUNQUAL Hydrology for file: P1ext-8345

Period of analysis: 24 years from 1975 to 1998

	Units in inches							
Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.6	0.1	0.0	0.7	1.8	0.0	0.0	2.5
FEB	2.42	0.17	0.0	0.96	1.29	0.0	0.0	2.25
MAR	3.28	0.49	0.0	0.97	1.83	0.0	0.0	2.79
APR	3.08	1.02	0.0	0.53	1.54	0.0	0.0	2.07
MAY	3.87	1.7	0.0	0.46	1.7	0.0	0.0	2.17
JUN	4.16	2.44	0.0	0.6	1.13	0.0	0.0	1.73
JUL	4.21	2.76	0.0	0.68	0.78	0.0	0.0	1.46
AUG	3.63	2.29	0.0	0.5	0.84	0.0	0.0	1.34
SEP	3.34	1.44	0.0	0.43	1.47	0.0	0.0	1.9
OCT	2.5	0.79	0.0	0.36	1.35	0.0	0.0	1.71
NOV	3.29	0.39	0.0	0.72	2.18	0.0	0.0	2.9
DEC	2.81	0.18	0.0	0.7	1.93	0.0	0.0	2.63
Totals	39.2	13.76	0.0	7.61	17.84	0.0	0.0	25.45

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine 1 – Existing Conditions

RUNQUAL Average Monthly Loads for file: P1ext-8345

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	3170	40	69	2	4
FEB	3798	30	69	1	5
MAR	3933	42	81	2	5
APR	2599	34	56	1	3
MAY	2422	37	57	2	3
JUN	2570	29	53	1	3
JUL	2625	21	47	1	3
AUG	2131	23	42	1	3
SEP	2263	34	51	1	3
OCT	1977	30	45	1	3
NOV	3356	48	78	2	5
DEC	3223	43	72	2	4
Totals	34067	411	719	18	44

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine 1 – Existing Conditions

RUNQUAL Hydrology for file: P1ext-8345

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	2	2.4	29	0.7	0.7	0.1	0.1
MD_Mixed	2	12.5	184	0.6	0.6	0.0	0.0
HD_Mixed	64	19.6	8542	4.2	4.2	0.3	0.3
LD_Residential	2	2.4	44	0.6	0.6	0.0	0.0
MD_Residential	2	5.0	103	0.6	0.6	0.1	0.1
HD_Residential	89	7.4	6108	13.8	13.8	1.2	1.2
Open_Land	121	1.6	3912		313.1		25.0
Subsurface				390.5	390.5	16.3	16.3
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			15144		0.8		1.5
Totals	284	7.6	34067	411	725	18	45

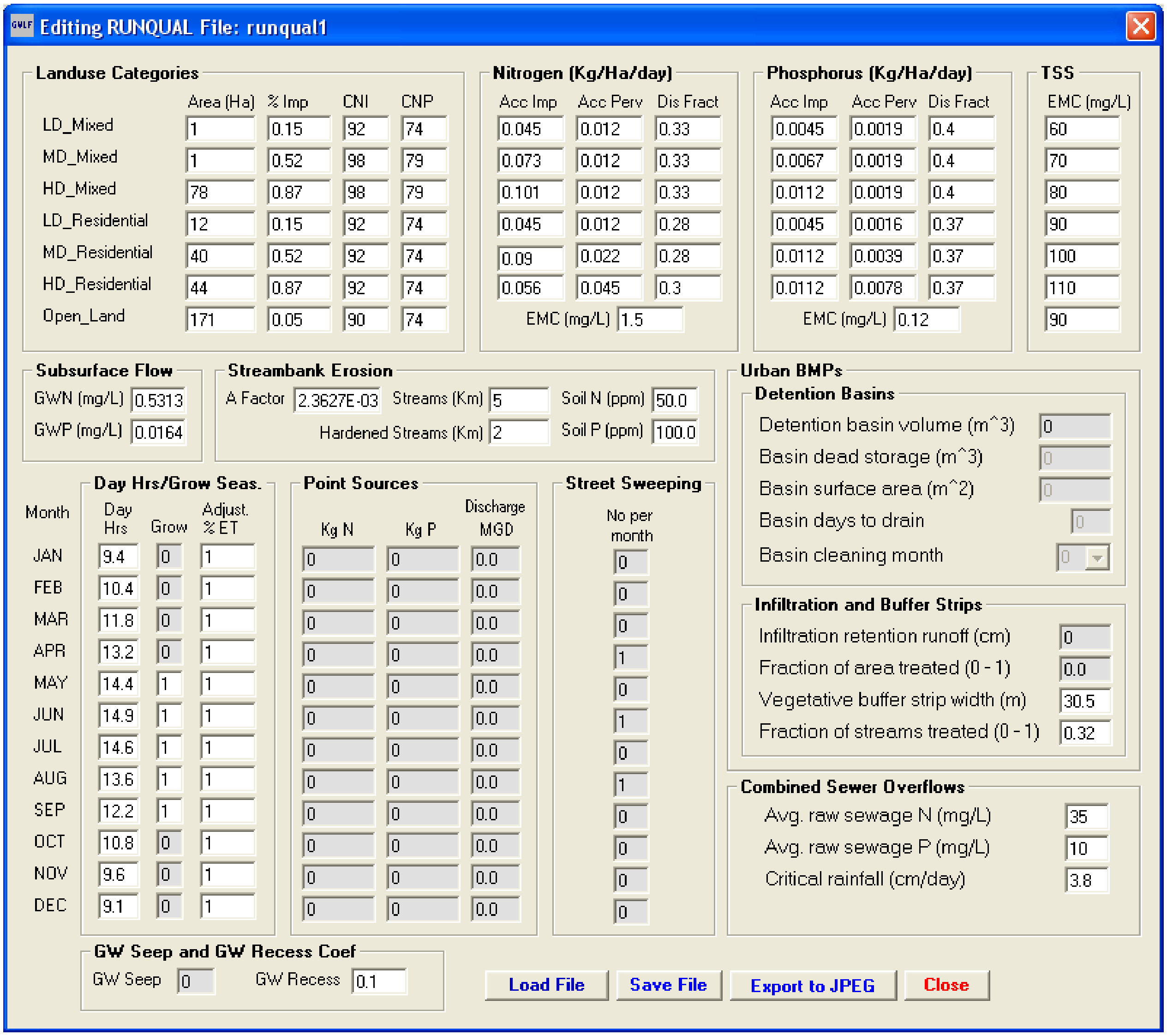
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source – Pine 1 - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Pine 2



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Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	1	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	1	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	78	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	12	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	40	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	44	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	171	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5 — Phosphorus EMC (mg/L) 0.12

Subsurface Flow: GWN (mg/L) 0.5313; GWP (mg/L) 0.0164

Streambank Erosion: A Factor 2.3627E-03; Streams (Km) 5; Soil N (ppm) 50.0; Hardened Streams (Km) 2; Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins

Detention basin volume (m^3)	0
Basin dead storage (m^3)	0
Basin surface area (m^2)	0
Basin days to drain	0
Basin cleaning month	0

Infiltration and Buffer Strips

Infiltration retention runoff (cm)	0
Fraction of area treated (0 - 1)	0.0
Vegetative buffer strip width (m)	30.5
Fraction of streams treated (0 - 1)	0.32

Combined Sewer Overflows

Avg. raw sewage N (mg/L)	35
Avg. raw sewage P (mg/L)	10
Critical rainfall (cm/day)	3.8

GW Seep and GW Recess Coef: GW Seep 0; GW Recess 0.1

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RUNQUAL Data Input - Pine 2 - Existing Conditions

RUNQUAL Hydrology for file: p2ext-1

Period of analysis: 24 years from 1975 to 1998

	Units in inches							
Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.6	0.11	0.0	0.62	1.86	0.0	0.0	2.48
FEB	2.42	0.2	0.0	0.85	1.37	0.0	0.0	2.22
MAR	3.28	0.58	0.0	0.86	1.84	0.0	0.0	2.71
APR	3.08	1.2	0.0	0.48	1.41	0.0	0.0	1.88
MAY	3.87	2.12	0.0	0.42	1.32	0.0	0.0	1.74
JUN	4.16	2.88	0.0	0.54	0.74	0.0	0.0	1.28
JUL	4.21	3.27	0.0	0.6	0.37	0.0	0.0	0.97
AUG	3.63	2.71	0.0	0.45	0.48	0.0	0.0	0.93
SEP	3.34	1.7	0.0	0.39	1.25	0.0	0.0	1.64
OCT	2.5	0.94	0.0	0.32	1.25	0.0	0.0	1.57
NOV	3.29	0.47	0.0	0.65	2.18	0.0	0.0	2.83
DEC	2.81	0.21	0.0	0.63	1.97	0.0	0.0	2.6
Totals	39.2	16.38	0.0	6.81	16.04	0.0	0.0	22.85

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine 2 – Existing Conditions

RUNQUAL Average Monthly Loads for file: p2ext-1

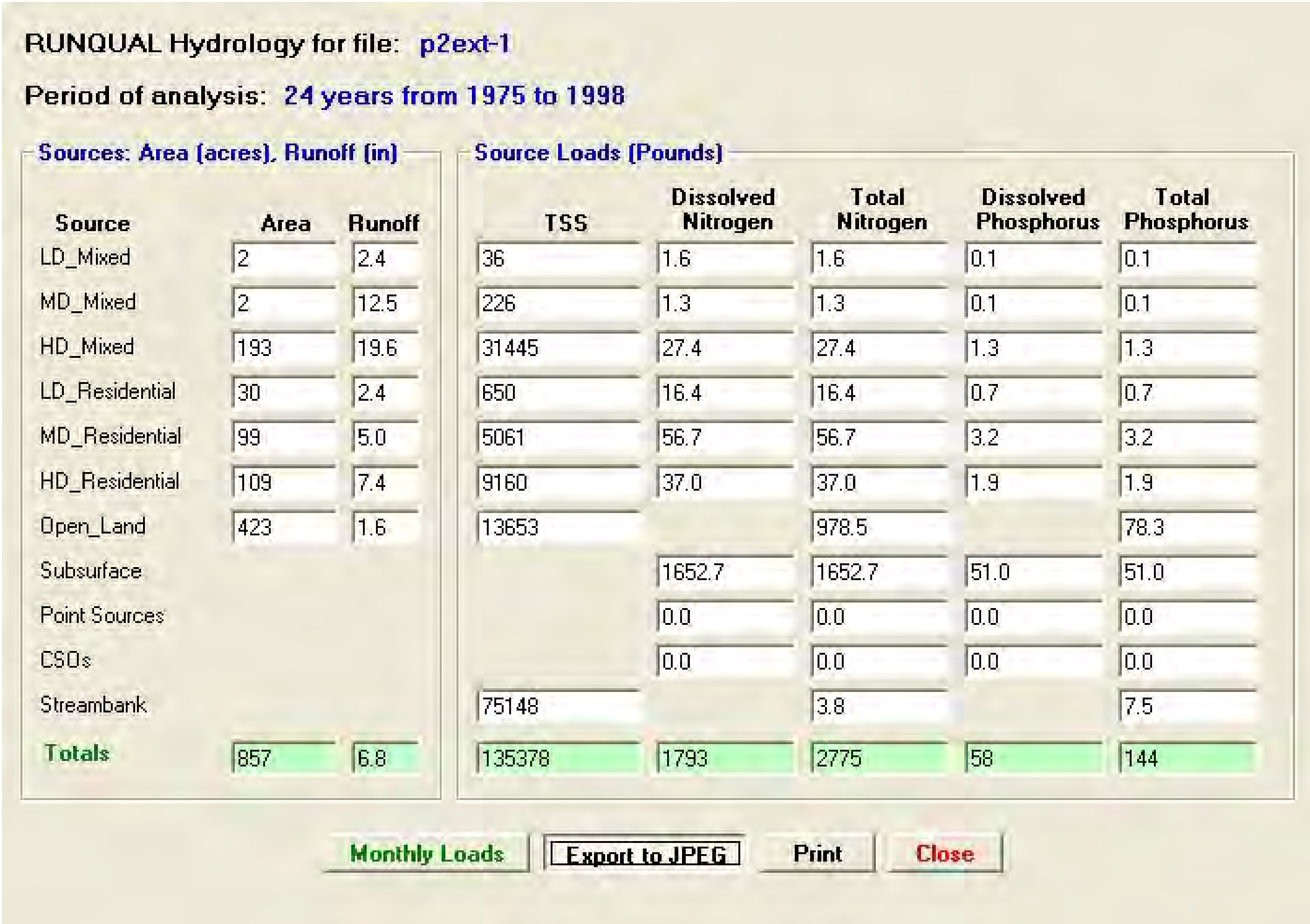
Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	13134	194	284	6	14
FEB	15026	145	267	5	16
MAR	15602	199	317	6	17
APR	10603	146	215	5	11
MAY	9316	139	198	4	10
JUN	9707	108	181	3	10
JUL	9189	73	146	2	9
AUG	7819	85	142	3	8
SEP	9268	139	195	4	9
OCT	8339	133	179	4	8
NOV	13959	226	320	7	16
DEC	13416	206	297	7	15
Totals	135378	1793	2740	58	142

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine 2 – Existing Conditions



RUNQUAL Hydrology for file: p2ext-1

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

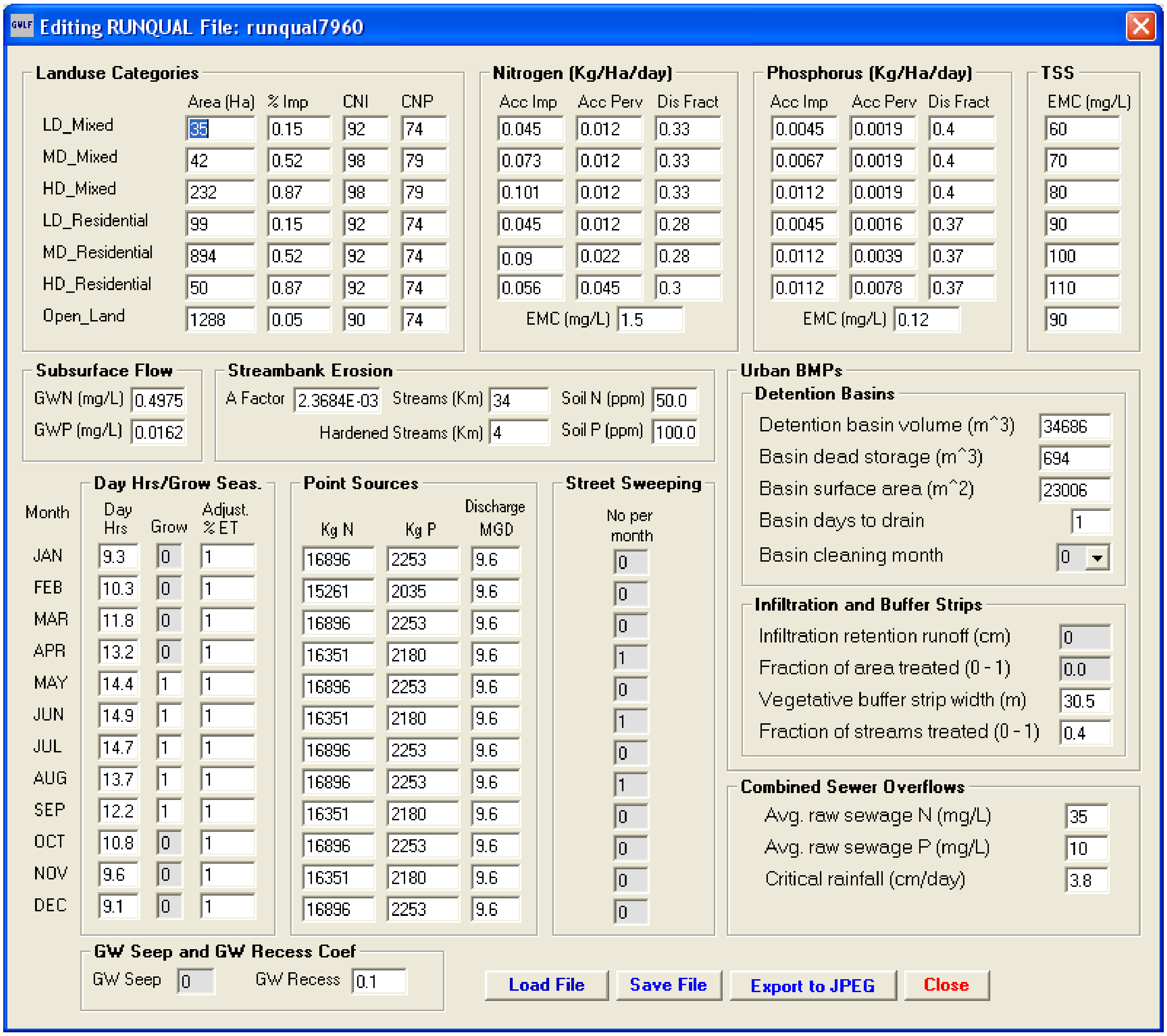
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	2	2.4	36	1.6	1.6	0.1	0.1
MD_Mixed	2	12.5	226	1.3	1.3	0.1	0.1
HD_Mixed	193	19.6	31445	27.4	27.4	1.3	1.3
LD_Residential	30	2.4	650	16.4	16.4	0.7	0.7
MD_Residential	99	5.0	5061	56.7	56.7	3.2	3.2
HD_Residential	109	7.4	9160	37.0	37.0	1.9	1.9
Open_Land	423	1.6	13653		978.5		78.3
Subsurface				1652.7	1652.7	51.0	51.0
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			75148		3.8		7.5
Totals	857	6.8	135378	1793	2775	58	144

Pollution Loading by Source - Pine 2 - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Pine 3



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Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	EMC (mg/L)
LD_Mixed	35	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	42	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	232	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	99	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	894	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	50	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	1288	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5; Phosphorus EMC (mg/L) 0.12

Subsurface Flow
GWN (mg/L) 0.4975
GWP (mg/L) 0.0162

Streambank Erosion
A Factor 2.3684E-03; Streams (Km) 34; Soil N (ppm) 50.0
Hardened Streams (Km) 4; Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	16896	2253	9.6	0
FEB	10.3	0	1	15261	2035	9.6	0
MAR	11.8	0	1	16896	2253	9.6	0
APR	13.2	0	1	16351	2180	9.6	1
MAY	14.4	1	1	16896	2253	9.6	0
JUN	14.9	1	1	16351	2180	9.6	1
JUL	14.7	1	1	16896	2253	9.6	0
AUG	13.7	1	1	16896	2253	9.6	1
SEP	12.2	1	1	16351	2180	9.6	0
OCT	10.8	0	1	16896	2253	9.6	0
NOV	9.6	0	1	16351	2180	9.6	0
DEC	9.1	0	1	16896	2253	9.6	0

Urban BMPs

Detention Basins
Detention basin volume (m^3) 34686
Basin dead storage (m^3) 694
Basin surface area (m^2) 23006
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips
Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.4

Combined Sewer Overflows
Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef
GW Seep 0; GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input - Pine 3 - Existing Conditions

RUNQUAL Hydrology for file: p3ext-7960

Period of analysis: 24 years from 1975 to 1998

Units in inches

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.85	0.13	0.0	0.47	2.25	1.67	0.0	4.39
FEB	2.45	0.22	0.0	0.76	1.47	1.51	0.0	3.74
MAR	3.24	0.65	0.0	0.65	1.93	1.67	0.0	4.26
APR	3.01	1.36	0.0	0.29	1.36	1.61	0.0	3.27
MAY	3.85	2.41	0.0	0.25	1.2	1.67	0.0	3.12
JUN	4.11	3.27	0.0	0.32	0.52	1.61	0.0	2.45
JUL	4.33	3.82	0.0	0.39	0.19	1.67	0.0	2.25
AUG	3.76	3.22	0.0	0.26	0.28	1.67	0.0	2.21
SEP	3.45	2.01	0.0	0.24	1.2	1.61	0.0	3.06
OCT	2.61	1.12	0.0	0.23	1.26	1.67	0.0	3.16
NOV	3.2	0.57	0.0	0.36	2.27	1.61	0.0	4.24
DEC	3.0	0.26	0.0	0.51	2.23	1.67	0.0	4.41
Totals	39.86	19.03	0.0	4.75	16.16	19.65	0.0	40.56

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine 3 – Existing Conditions

RUNQUAL Average Monthly Loads for file: p3ext-7960

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	401192	38931	39458	5027	5105
FEB	406164	34770	35615	4532	4633
MAR	405728	38700	39425	5020	5113
APR	335300	37059	37391	4841	4898
MAY	310562	38132	38418	4997	5048
JUN	268560	36434	36791	4820	4872
JUL	249523	37347	37784	4972	5029
AUG	246901	37459	37755	4975	5021
SEP	310848	36937	37211	4836	4886
OCT	317077	38186	38447	4999	5049
NOV	390591	37730	38138	4863	4931
DEC	405490	38921	39494	5027	5109
Totals	4047936	450606	455929	58909	59694

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine 3 – Existing Conditions

RUNQUAL Hydrology for file: p3ext-7960

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	86	2.4	1100	6.8	6.8	1.3	1.3
MD_Mixed	104	12.8	8207	6.6	6.6	1.3	1.3
HD_Mixed	573	19.9	80804	9.9	9.9	1.9	1.9
LD_Residential	245	2.4	4669	16.3	16.6	2.9	2.9
MD_Residential	2209	5.1	98548	152.1	155.1	35.6	35.9
HD_Residential	124	7.6	9072	5.0	5.0	1.1	1.1
Open_Land	3183	1.6	105650		5136.1		410.9
Subsurface				11828.6	11828.6	385.2	385.2
Point Sources				438580.5	438580.5	58479.8	58479.8
CSOs				0.0	0.0	0.0	0.0
Streambank			3739886		187.0		374.0
Totals	6524	4.7	4047936	450606	455932	58909	59694

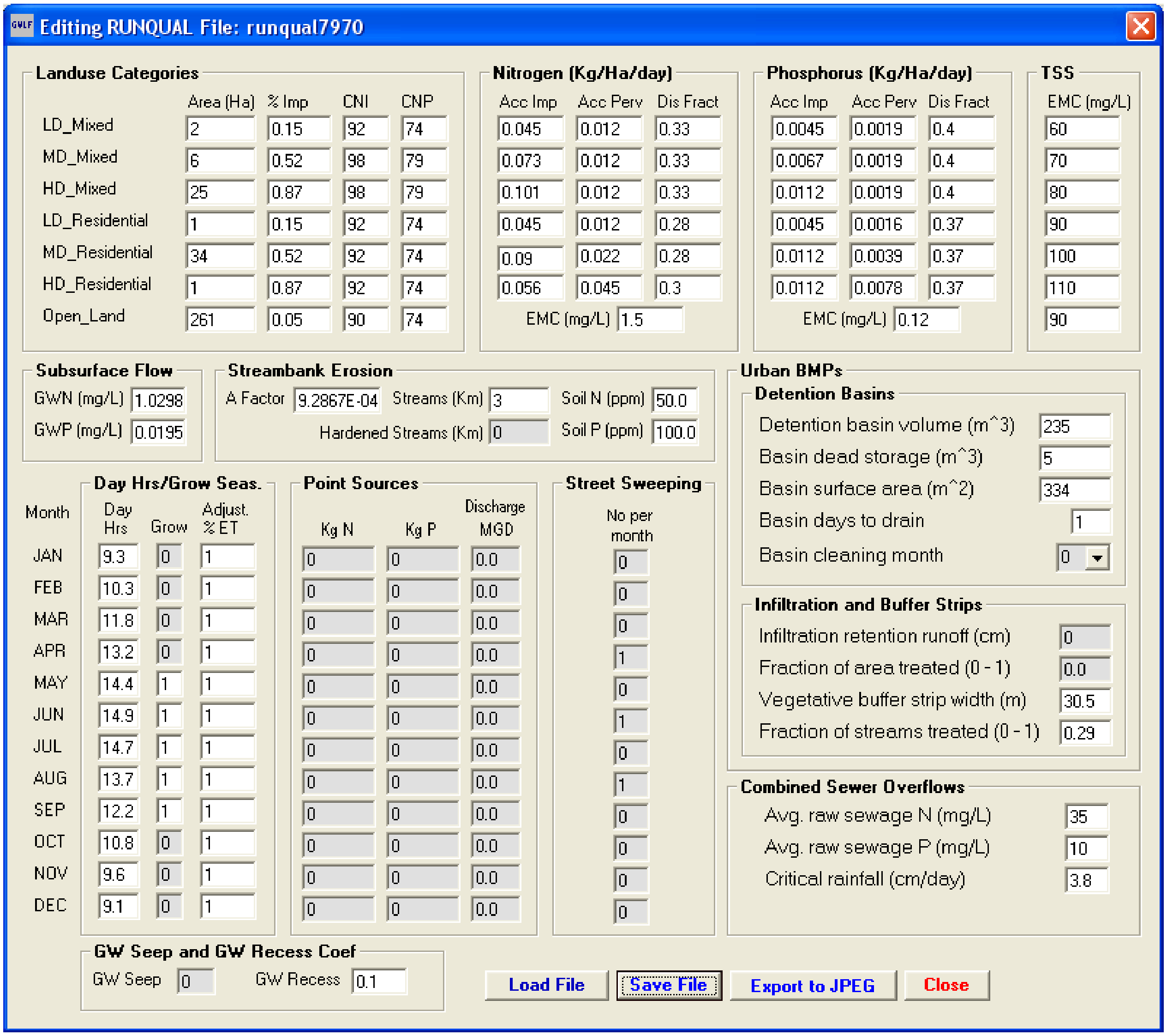
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Pine 3 - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Pine 4



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Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	2	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	6	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	25	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	1	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	34	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	1	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	261	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5; Phosphorus EMC (mg/L) 0.12

Subsurface Flow: GWN (mg/L) 1.0298; GWP (mg/L) 0.0195

Streambank Erosion: A Factor 9.2867E-04; Streams (Km) 3; Soil N (ppm) 50.0; Hardened Streams (Km) 0; Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	0	0	0.0	0
FEB	10.3	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.7	1	1	0	0	0.0	0
AUG	13.7	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins

Detention basin volume (m^3)	235
Basin dead storage (m^3)	5
Basin surface area (m^2)	334
Basin days to drain	1
Basin cleaning month	0

Infiltration and Buffer Strips

Infiltration retention runoff (cm)	0
Fraction of area treated (0 - 1)	0.0
Vegetative buffer strip width (m)	30.5
Fraction of streams treated (0 - 1)	0.29

Combined Sewer Overflows

Avg. raw sewage N (mg/L)	35
Avg. raw sewage P (mg/L)	10
Critical rainfall (cm/day)	3.8

GW Seep and GW Recess Coef: GW Seep 0; GW Recess 0.1

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RUNQUAL Data Input - Pine 4 - Existing Conditions

RUNQUAL Hydrology for file: p4extwonp-7970

Period of analysis: 24 years from 1975 to 1998

Units in inches

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.85	0.14	0.0	0.36	2.35	0.0	0.0	2.71
FEB	2.45	0.23	0.0	0.6	1.62	0.0	0.0	2.22
MAR	3.24	0.71	0.0	0.5	2.02	0.0	0.0	2.53
APR	3.01	1.48	0.0	0.21	1.32	0.0	0.0	1.53
MAY	3.85	2.62	0.0	0.19	1.07	0.0	0.0	1.26
JUN	4.11	3.56	0.0	0.24	0.31	0.0	0.0	0.54
JUL	4.33	4.16	0.0	0.29	0.11	0.0	0.0	0.4
AUG	3.76	3.49	0.0	0.19	0.09	0.0	0.0	0.28
SEP	3.45	2.17	0.0	0.17	1.1	0.0	0.0	1.27
OCT	2.61	1.22	0.0	0.17	1.22	0.0	0.0	1.39
NOV	3.2	0.62	0.0	0.27	2.3	0.0	0.0	2.58
DEC	3.0	0.28	0.0	0.41	2.31	0.0	0.0	2.72
Totals	39.86	20.69	0.0	3.6	15.83	0.0	0.0	19.43

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine 4 – Existing Conditions

RUNQUAL Average Monthly Loads for file: p4extwonp-7970

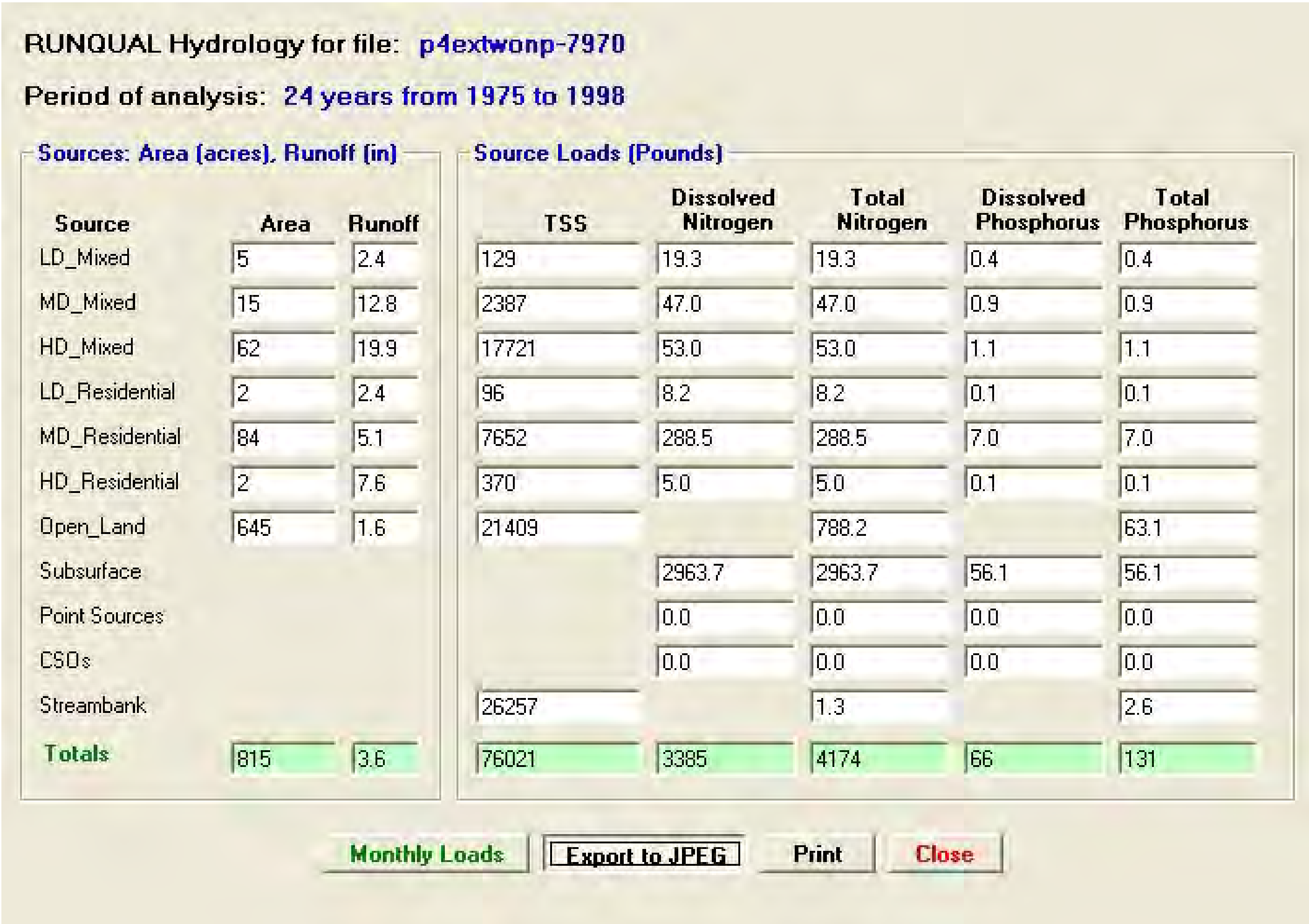
Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	8049	449	527	9	15
FEB	11113	311	441	6	17
MAR	9901	394	499	8	17
APR	5108	253	298	5	9
MAY	4247	230	267	4	8
JUN	4625	150	198	3	7
JUL	4987	111	158	2	6
AUG	3732	118	152	2	5
SEP	4225	241	276	5	8
OCT	4448	248	285	5	8
NOV	6816	439	499	8	14
DEC	8772	441	531	9	16
Totals	76021	3385	4130	66	129

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine 4 – Existing Conditions



RUNQUAL Hydrology for file: p4extwonp-7970

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

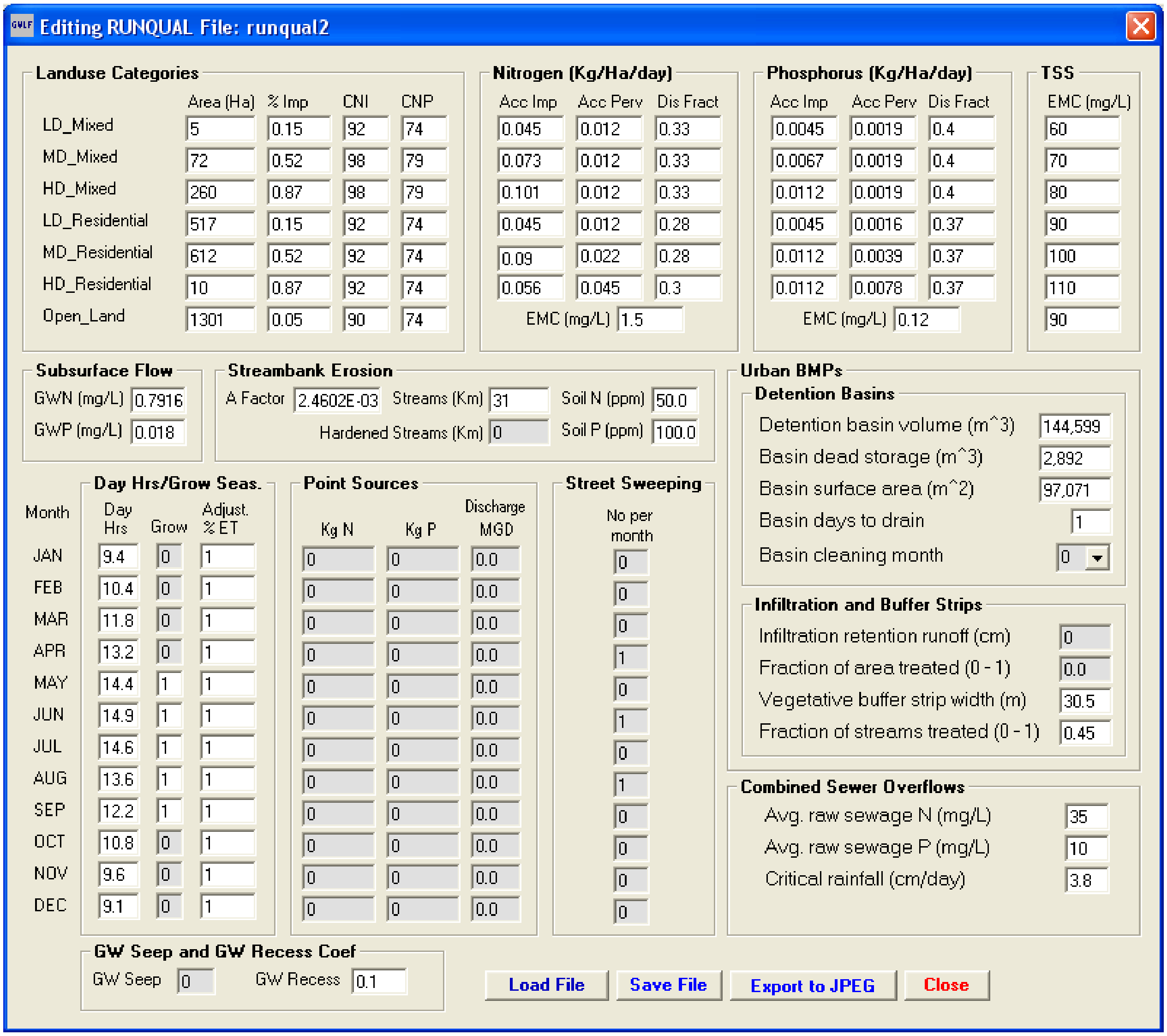
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	5	2.4	129	19.3	19.3	0.4	0.4
MD_Mixed	15	12.8	2387	47.0	47.0	0.9	0.9
HD_Mixed	62	19.9	17721	53.0	53.0	1.1	1.1
LD_Residential	2	2.4	96	8.2	8.2	0.1	0.1
MD_Residential	84	5.1	7652	288.5	288.5	7.0	7.0
HD_Residential	2	7.6	370	5.0	5.0	0.1	0.1
Open_Land	645	1.6	21409		788.2		63.1
Subsurface				2963.7	2963.7	56.1	56.1
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			26257		1.3		2.6
Totals	815	3.6	76021	3385	4174	66	131

Pollution Loading by Source - Pine 4 - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Pine 5



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Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	5	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	72	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	260	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	517	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	612	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	10	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	1301	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5 — Phosphorus EMC (mg/L) 0.12

Subsurface Flow
GWN (mg/L) 0.7916
GWP (mg/L) 0.018

Streambank Erosion
A Factor 2.4602E-03 Streams (Km) 31 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins
Detention basin volume (m^3) 144,599
Basin dead storage (m^3) 2,892
Basin surface area (m^2) 97,071
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips
Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.45

Combined Sewer Overflows
Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef
GW Seep 0 GW Recess 0.1

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RUNQUAL Data Input - Pine 5 - Existing Conditions

RUNQUAL Hydrology for file: p5ext-2

Period of analysis: 24 years from 1975 to 1998

	Units in inches							
Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.56	0.17	0.0	0.46	1.92	0.0	0.0	2.38
FEB	2.28	0.29	0.0	0.5	1.49	0.0	0.0	1.99
MAR	3.11	0.8	0.0	0.49	1.81	0.0	0.0	2.3
APR	2.96	1.63	0.0	0.26	1.07	0.0	0.0	1.33
MAY	3.68	2.86	0.0	0.2	0.72	0.0	0.0	0.93
JUN	4.03	3.85	0.0	0.3	0.12	0.0	0.0	0.43
JUL	3.92	4.36	0.0	0.33	0.0	0.0	0.0	0.33
AUG	3.41	3.51	0.0	0.24	0.0	0.0	0.0	0.24
SEP	3.23	2.25	0.0	0.2	0.78	0.0	0.0	0.98
OCT	2.31	1.25	0.0	0.17	0.89	0.0	0.0	1.06
NOV	3.03	0.63	0.0	0.34	2.06	0.0	0.0	2.4
DEC	2.81	0.3	0.0	0.4	2.1	0.0	0.0	2.51
Totals	37.31	21.9	0.0	3.91	12.97	0.0	0.0	16.89

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Pine 5 – Existing Conditions

RUNQUAL Average Monthly Loads for file: p5ext-2

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	311924	2391	2911	59	128
FEB	298436	1873	2428	48	118
MAR	305293	2289	2808	57	126
APR	203163	1345	1636	32	73
MAY	150537	1141	1337	26	56
JUN	125345	577	846	14	48
JUL	91858	488	712	13	38
AUG	109875	668	882	16	43
SEP	180912	1323	1541	31	64
OCT	177581	1225	1416	29	60
NOV	303668	2546	2933	61	118
DEC	317918	2615	3071	64	128
Totals	2576510	18480	22523	451	1000

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Pine 5 – Existing Conditions

RUNQUAL Hydrology for file: p5ext-2

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	12	2.0	153	19.6	19.6	0.5	0.5
MD_Mixed	178	11.3	15070	235.9	235.9	6.5	6.5
HD_Mixed	642	17.8	97870	230.7	230.7	6.4	6.4
LD_Residential	1278	2.0	23653	1716.9	1716.9	43.6	43.6
MD_Residential	1512	4.2	67728	2104.1	2104.1	71.1	71.1
HD_Residential	25	6.4	1840	20.4	20.4	0.6	0.6
Open_Land	3215	1.3	82446		4276.6		342.1
Subsurface				14152.0	14152.0	321.8	321.8
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			2287750		114.4		228.8
Totals	6862	3.9	2576510	18480	22871	451	1022

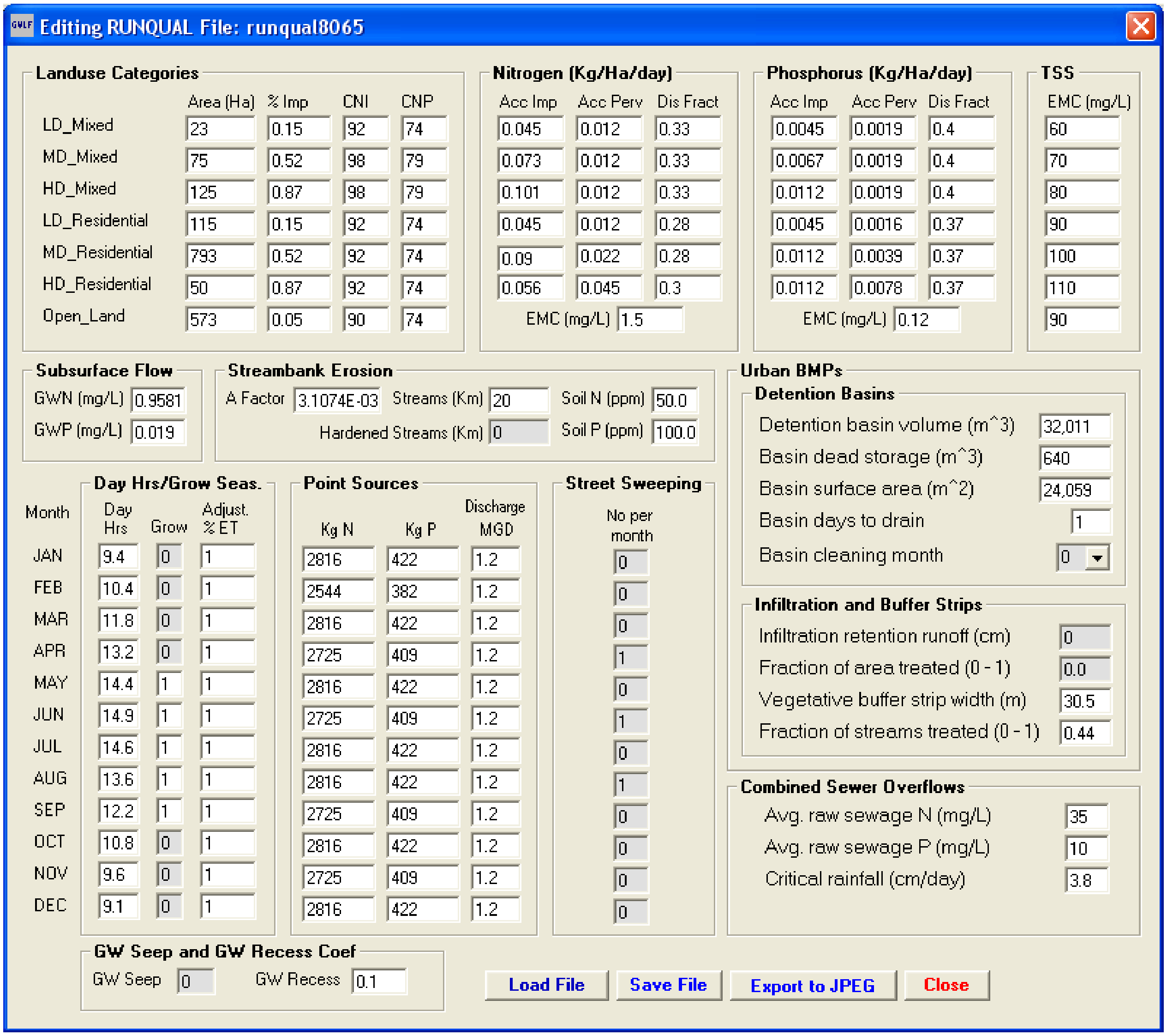
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Pine 5 - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Little Pine West



RUNQUAL Data Input - Little Pine West - Existing Conditions

RUNQUAL Hydrology for file: lpwext-8065

Period of analysis: 24 years from 1975 to 1998

	Units in inches							
Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.56	0.15	0.0	0.52	1.88	0.31	0.0	2.72
FEB	2.28	0.25	0.0	0.57	1.46	0.28	0.0	2.31
MAR	3.11	0.71	0.0	0.55	1.85	0.31	0.0	2.71
APR	2.96	1.43	0.0	0.3	1.23	0.3	0.0	1.83
MAY	3.68	2.51	0.0	0.23	0.99	0.31	0.0	1.54
JUN	4.03	3.39	0.0	0.33	0.31	0.3	0.0	0.94
JUL	3.92	3.84	0.0	0.38	0.0	0.31	0.0	0.7
AUG	3.41	3.19	0.0	0.27	0.03	0.31	0.0	0.61
SEP	3.23	2.0	0.0	0.23	0.99	0.3	0.0	1.53
OCT	2.31	1.1	0.0	0.19	1.02	0.31	0.0	1.52
NOV	3.03	0.56	0.0	0.38	2.09	0.3	0.0	2.78
DEC	2.81	0.26	0.0	0.46	2.08	0.31	0.0	2.86
Totals	37.31	19.41	0.0	4.42	13.93	3.69	0.0	22.05

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Little Pine West – Existing Conditions

RUNQUAL Average Monthly Loads for file: lpwext-8065

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	202735	8002	8263	971	1010
FEB	195915	7009	7290	875	915
MAR	202878	7968	8244	970	1010
APR	155499	7168	7321	926	953
MAY	121061	7086	7203	948	969
JUN	111996	6304	6468	909	932
JUL	75192	5935	6122	927	948
AUG	84552	6164	6296	931	948
SEP	134607	6944	7063	921	943
OCT	132638	7172	7270	951	971
NOV	201579	7989	8182	943	977
DEC	207196	8188	8421	974	1011
Totals	1825849	85929	88143	11245	11586

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Little Pine West – Existing Conditions

RUNQUAL Hydrology for file: lpwext-8065

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	57	2.0	386	3.6	3.6	0.7	0.7
MD_Mixed	185	11.3	8641	9.8	9.8	1.9	1.9
HD_Mixed	309	17.8	25900	4.4	4.4	0.8	0.8
LD_Residential	284	2.0	2897	15.2	15.5	2.7	2.7
MD_Residential	1960	4.2	48323	108.7	110.9	25.5	25.7
HD_Residential	124	6.4	5065	4.1	4.1	0.9	0.9
Open_Land	1416	1.3	36312		2128.8		170.3
Subsurface				12686.9	12686.9	251.6	251.6
Point Sources				73096.4	73096.4	10961.4	10961.4
CSOs				0.0	0.0	0.0	0.0
Streambank			1698323		84.9		169.8
Totals	4334	4.4	1825849	85929	88145	11245	11586

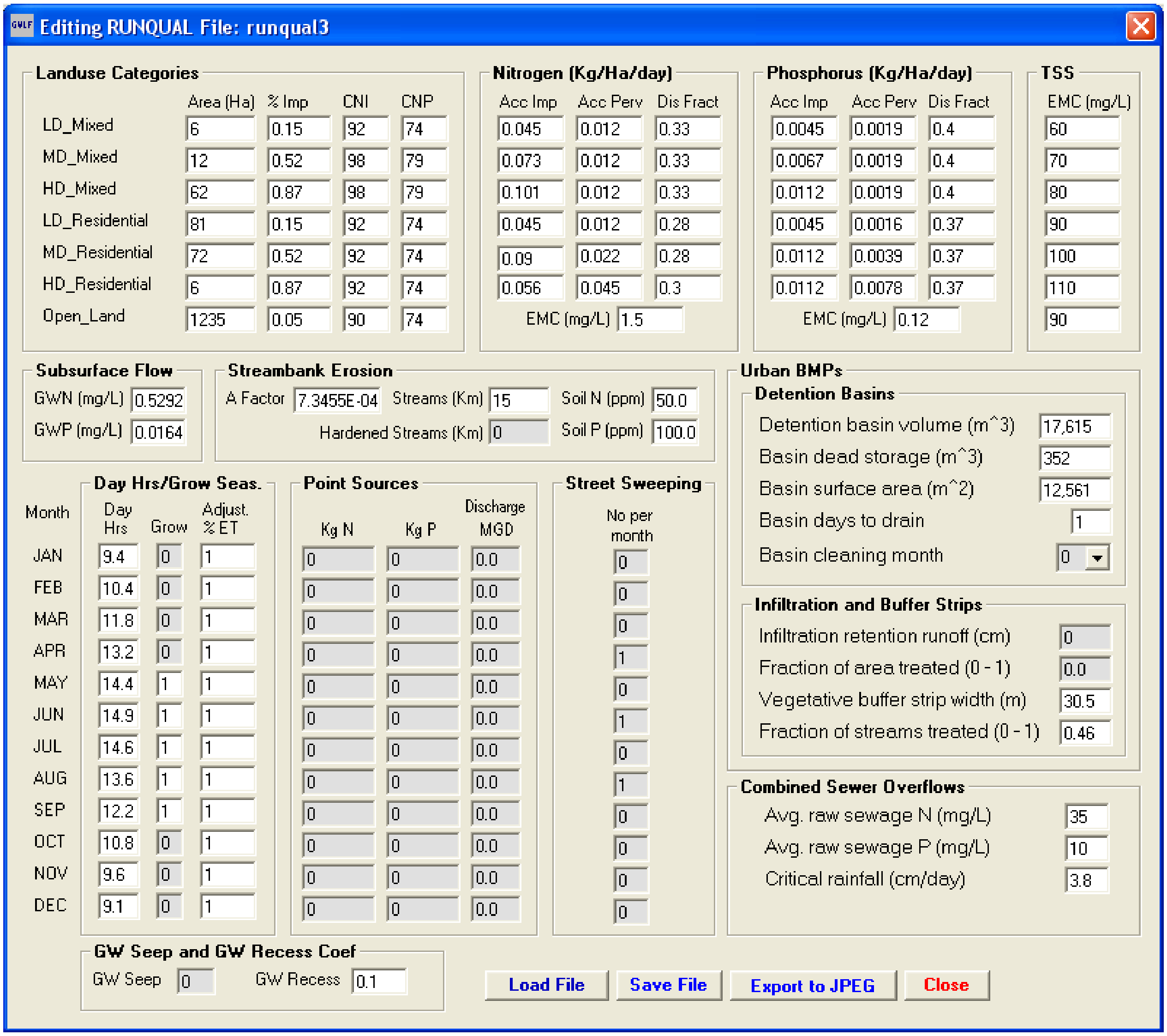
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Little Pine West - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Little Pine East



Editing RUNQUAL File: runqual3

Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	6	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	12	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	62	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	81	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	72	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	6	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	1235	0.05	90	74							90

Nitrogen EMC (mg/L) 1.5 — Phosphorus EMC (mg/L) 0.12

Subsurface Flow
GWN (mg/L) 0.5292
GWP (mg/L) 0.0164

Streambank Erosion
A Factor 7.3455E-04 Streams (Km) 15 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins
Detention basin volume (m^3) 17,615
Basin dead storage (m^3) 352
Basin surface area (m^2) 12,561
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips
Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.46

Combined Sewer Overflows
Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef
GW Seep 0 GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input - Little Pine East - Existing Conditions

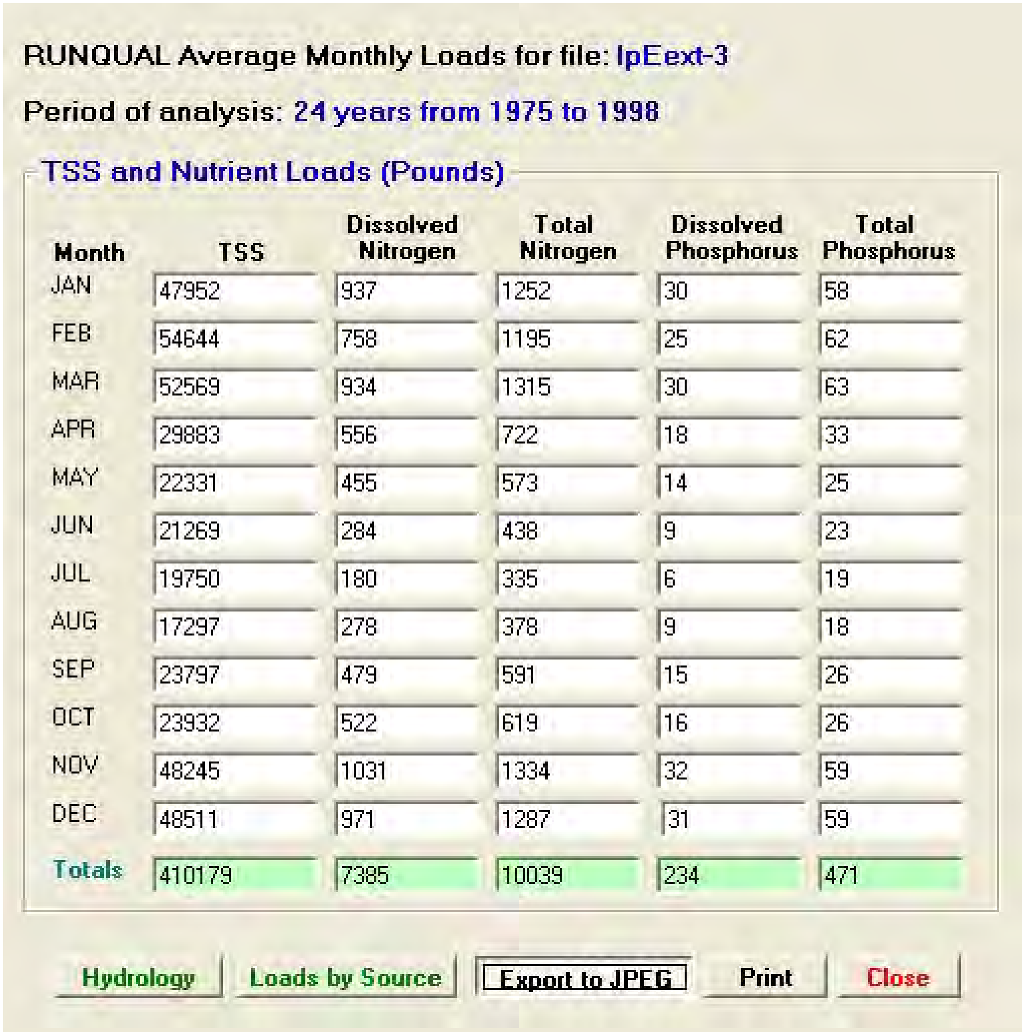
RUNQUAL Hydrology for file: lpEext-3

Period of analysis: 24 years from 1975 to 1998

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
	Units in inches							
JAN	2.6	0.16	0.0	0.3	2.13	0.0	0.0	2.44
FEB	2.42	0.27	0.0	0.42	1.72	0.0	0.0	2.14
MAR	3.28	0.8	0.0	0.38	2.1	0.0	0.0	2.48
APR	3.08	1.68	0.0	0.17	1.24	0.0	0.0	1.41
MAY	3.87	2.96	0.0	0.12	0.86	0.0	0.0	0.98
JUN	4.16	4.02	0.0	0.17	0.19	0.0	0.0	0.37
JUL	4.21	4.56	0.0	0.19	0.0	0.0	0.0	0.19
AUG	3.63	3.64	0.0	0.13	0.05	0.0	0.0	0.17
SEP	3.34	2.33	0.0	0.11	0.9	0.0	0.0	1.01
OCT	2.5	1.3	0.0	0.09	1.1	0.0	0.0	1.2
NOV	3.29	0.65	0.0	0.29	2.35	0.0	0.0	2.64
DEC	2.81	0.3	0.0	0.3	2.21	0.0	0.0	2.52
Totals	39.2	22.67	0.0	2.68	14.87	0.0	0.0	17.55

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Little Pine East – Existing Conditions



RUNQUAL Average Monthly Loads for file: lpEext-3

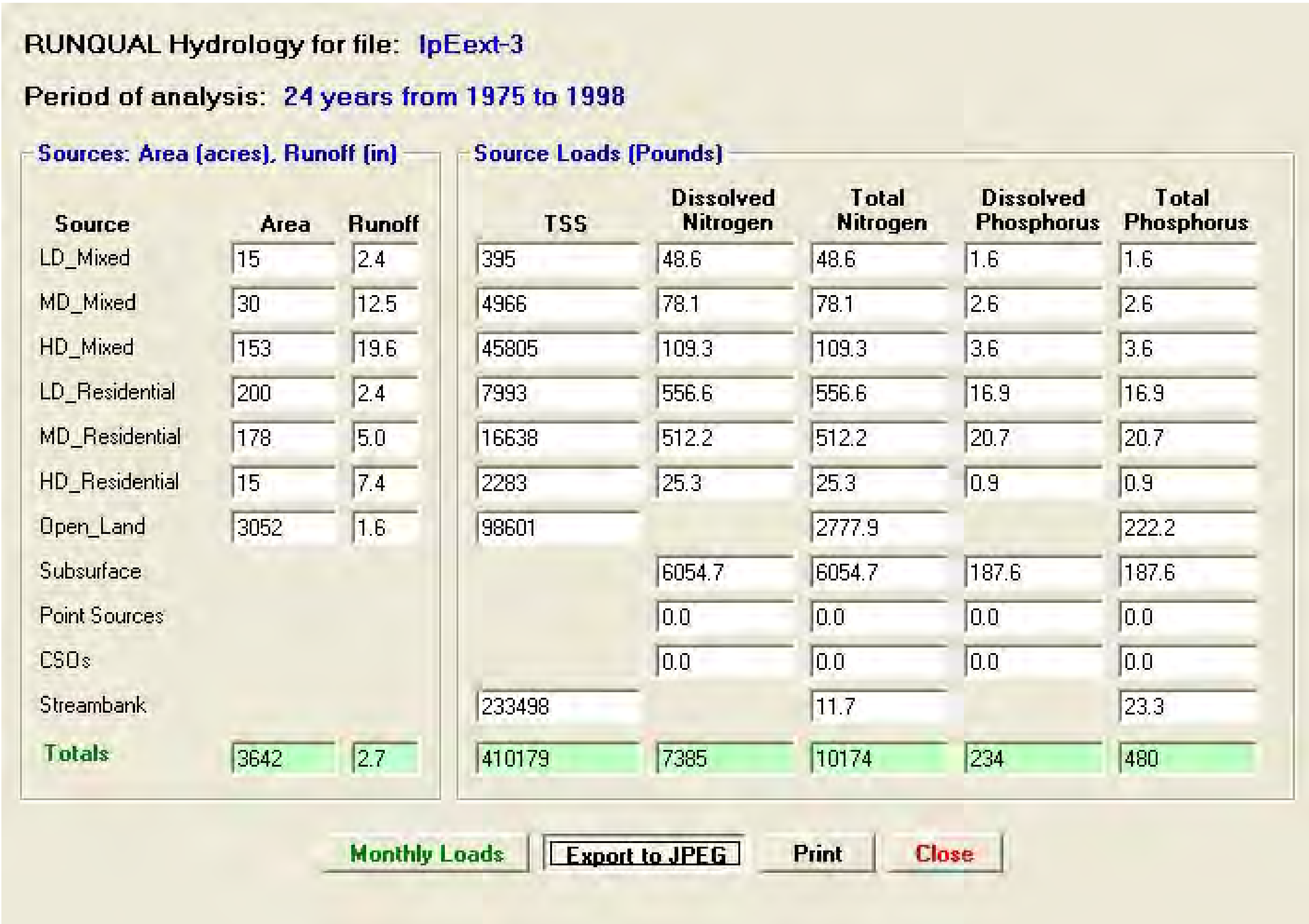
Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	47952	937	1252	30	58
FEB	54644	758	1195	25	62
MAR	52569	934	1315	30	63
APR	29883	556	722	18	33
MAY	22331	455	573	14	25
JUN	21269	284	438	9	23
JUL	19750	180	335	6	19
AUG	17297	278	378	9	18
SEP	23797	479	591	15	26
OCT	23932	522	619	16	26
NOV	48245	1031	1334	32	59
DEC	48511	971	1287	31	59
Totals	410179	7385	10039	234	471

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Little Pine East – Existing Conditions



RUNQUAL Hydrology for file: lpEext-3

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	15	2.4	395	48.6	48.6	1.6	1.6
MD_Mixed	30	12.5	4966	78.1	78.1	2.6	2.6
HD_Mixed	153	19.6	45805	109.3	109.3	3.6	3.6
LD_Residential	200	2.4	7993	556.6	556.6	16.9	16.9
MD_Residential	178	5.0	16638	512.2	512.2	20.7	20.7
HD_Residential	15	7.4	2283	25.3	25.3	0.9	0.9
Open_Land	3052	1.6	98601		2777.9		222.2
Subsurface				6054.7	6054.7	187.6	187.6
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			233498		11.7		23.3
Totals	3642	2.7	410179	7385	10174	234	480

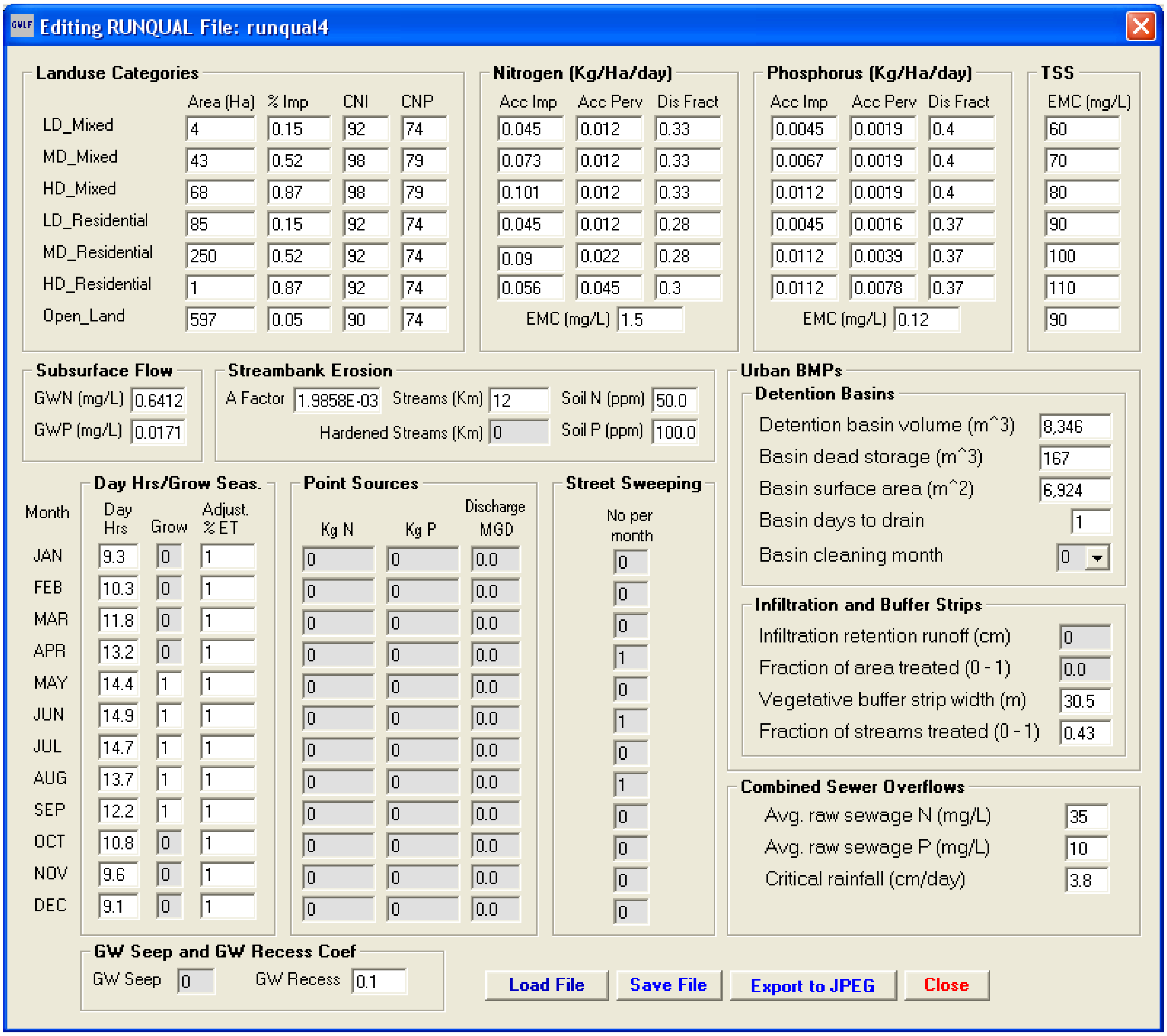
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Little Pine East - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Gourdhead & McCaslin


Editing RUNQUAL File: runqual4

Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	EMC (mg/L)
LD_Mixed	4	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	43	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	68	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	85	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	250	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	1	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	597	0.05	90	74	EMC (mg/L) 1.5			EMC (mg/L) 0.12			90

Subsurface Flow
GWN (mg/L) 0.6412
GWP (mg/L) 0.0171

Streambank Erosion
A Factor 1.9858E-03 Streams (Km) 12 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	0	0	0.0	0
FEB	10.3	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.7	1	1	0	0	0.0	0
AUG	13.7	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins
Detention basin volume (m^3) 8,346
Basin dead storage (m^3) 167
Basin surface area (m^2) 6,924
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips
Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.43

Combined Sewer Overflows
Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef
GW Seep 0 GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input - Gourdhead & McCaslin - Existing Conditions

RUNQUAL Hydrology for file: gmext-4

Period of analysis: 24 years from 1975 to 1998

	Units in inches							
Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.85	0.14	0.0	0.42	2.29	0.0	0.0	2.71
FEB	2.45	0.23	0.0	0.68	1.53	0.0	0.0	2.22
MAR	3.24	0.71	0.0	0.58	1.95	0.0	0.0	2.53
APR	3.01	1.47	0.0	0.25	1.29	0.0	0.0	1.54
MAY	3.85	2.61	0.0	0.22	1.05	0.0	0.0	1.27
JUN	4.11	3.55	0.0	0.28	0.29	0.0	0.0	0.56
JUL	4.33	4.14	0.0	0.34	0.09	0.0	0.0	0.44
AUG	3.76	3.42	0.0	0.23	0.11	0.0	0.0	0.34
SEP	3.45	2.16	0.0	0.21	1.08	0.0	0.0	1.28
OCT	2.61	1.22	0.0	0.2	1.2	0.0	0.0	1.4
NOV	3.2	0.62	0.0	0.32	2.26	0.0	0.0	2.58
DEC	3.0	0.28	0.0	0.46	2.26	0.0	0.0	2.72
Totals	39.86	20.55	0.0	4.18	15.41	0.0	0.0	19.59

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Gourdhead & McCaslin – Existing Conditions

RUNQUAL Average Monthly Loads for file: gmext-4

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	65546	872	1083	25	47
FEB	70311	594	937	19	51
MAR	67883	762	1041	22	50
APR	44833	489	616	14	27
MAY	35301	447	549	12	23
JUN	31759	289	417	8	21
JUL	28464	212	338	6	19
AUG	25288	228	319	6	16
SEP	37838	467	566	13	24
OCT	40763	484	583	13	25
NOV	60887	857	1018	24	42
DEC	67359	861	1095	25	49
Totals	576233	6561	8563	187	393

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Gourdhead & McCaslin – Existing Conditions

RUNQUAL Hydrology for file: gmext-4

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	10	2.4	162	10.0	10.0	0.4	0.4
MD_Mixed	106	12.8	10851	87.4	87.4	3.2	3.2
HD_Mixed	168	19.9	30587	37.4	37.4	1.4	1.4
LD_Residential	210	2.4	5173	180.7	180.7	6.0	6.0
MD_Residential	618	5.1	35576	550.2	550.2	24.3	24.3
HD_Residential	2	7.6	234	1.3	1.3	0.1	0.1
Open_Land	1475	1.6	48970		2095.3		167.6
Subsurface				5694.0	5694.0	151.9	151.9
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			444680		22.2		44.5
Totals	2590	4.2	576233	6561	8679	187	399

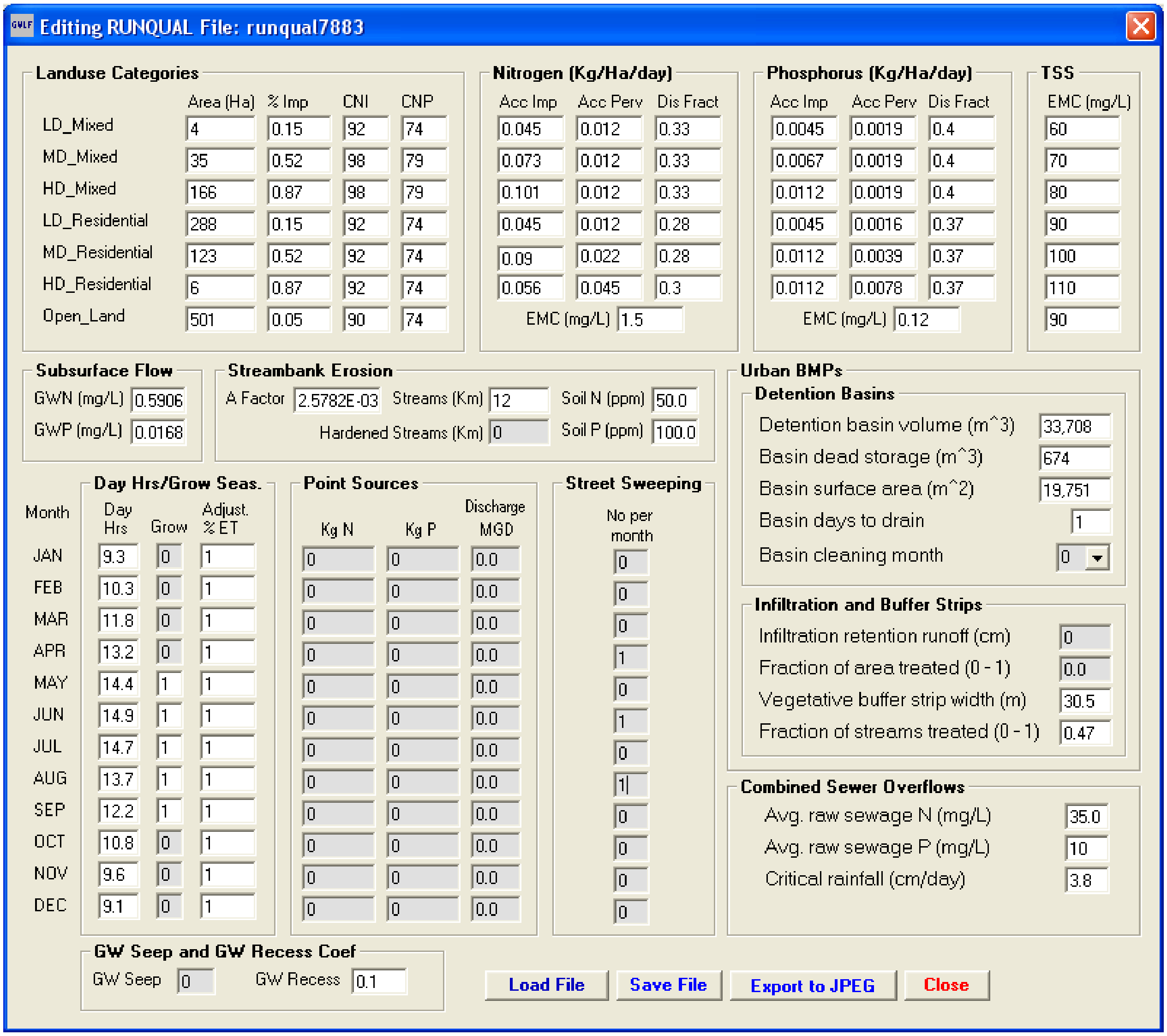
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Gourdhead & McCaslin - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Crouse



RUNQUAL Data Input - Crouse- Existing Conditions

RUNQUAL Hydrology for file: crousext-7883

Period of analysis: 24 years from 1975 to 1998

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
	Units in inches							
JAN	2.85	0.14	0.0	0.5	2.21	0.0	0.0	2.71
FEB	2.45	0.24	0.0	0.79	1.42	0.0	0.0	2.21
MAR	3.24	0.72	0.0	0.7	1.82	0.0	0.0	2.52
APR	3.01	1.49	0.0	0.34	1.18	0.0	0.0	1.53
MAY	3.85	2.64	0.0	0.31	0.95	0.0	0.0	1.25
JUN	4.11	3.58	0.0	0.39	0.18	0.0	0.0	0.56
JUL	4.33	4.18	0.0	0.45	0.04	0.0	0.0	0.49
AUG	3.76	3.4	0.0	0.32	0.05	0.0	0.0	0.37
SEP	3.45	2.18	0.0	0.29	0.97	0.0	0.0	1.26
OCT	2.61	1.23	0.0	0.27	1.12	0.0	0.0	1.38
NOV	3.2	0.63	0.0	0.41	2.17	0.0	0.0	2.57
DEC	3.0	0.28	0.0	0.54	2.18	0.0	0.0	2.72
Totals	39.86	20.7	0.0	5.32	14.28	0.0	0.0	19.59

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Crouse – Existing Conditions

RUNQUAL Average Monthly Loads for file: crousext-7883

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	84497	831	1045	26	50
FEB	87322	551	883	19	52
MAR	85846	713	992	22	52
APR	58767	445	590	13	30
MAY	46325	407	526	12	25
JUN	40916	246	390	7	22
JUL	35488	177	312	6	20
AUG	33239	196	302	6	17
SEP	50007	427	544	13	26
OCT	53702	448	562	13	27
NOV	79823	810	986	24	45
DEC	86001	822	1053	25	51
Totals	741932	6074	8184	186	416

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Crouse – Existing Conditions

RUNQUAL Hydrology for file: crousext-7883

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	10	2.4	137	8.8	8.8	0.4	0.4
MD_Mixed	86	12.8	7441	62.3	62.3	2.6	2.6
HD_Mixed	410	19.9	62906	80.0	80.0	3.4	3.4
LD_Residential	712	2.4	14781	536.1	536.1	20.6	20.6
MD_Residential	304	5.1	14755	237.0	237.0	12.1	12.1
HD_Residential	15	7.6	1185	6.9	6.9	0.3	0.3
Open_Land	1238	1.6	41095		2238.7		179.1
Subsurface				5143.0	5143.0	146.3	146.3
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			599632		30.0		60.0
Totals	2775	5.3	741932	6074	8343	186	425

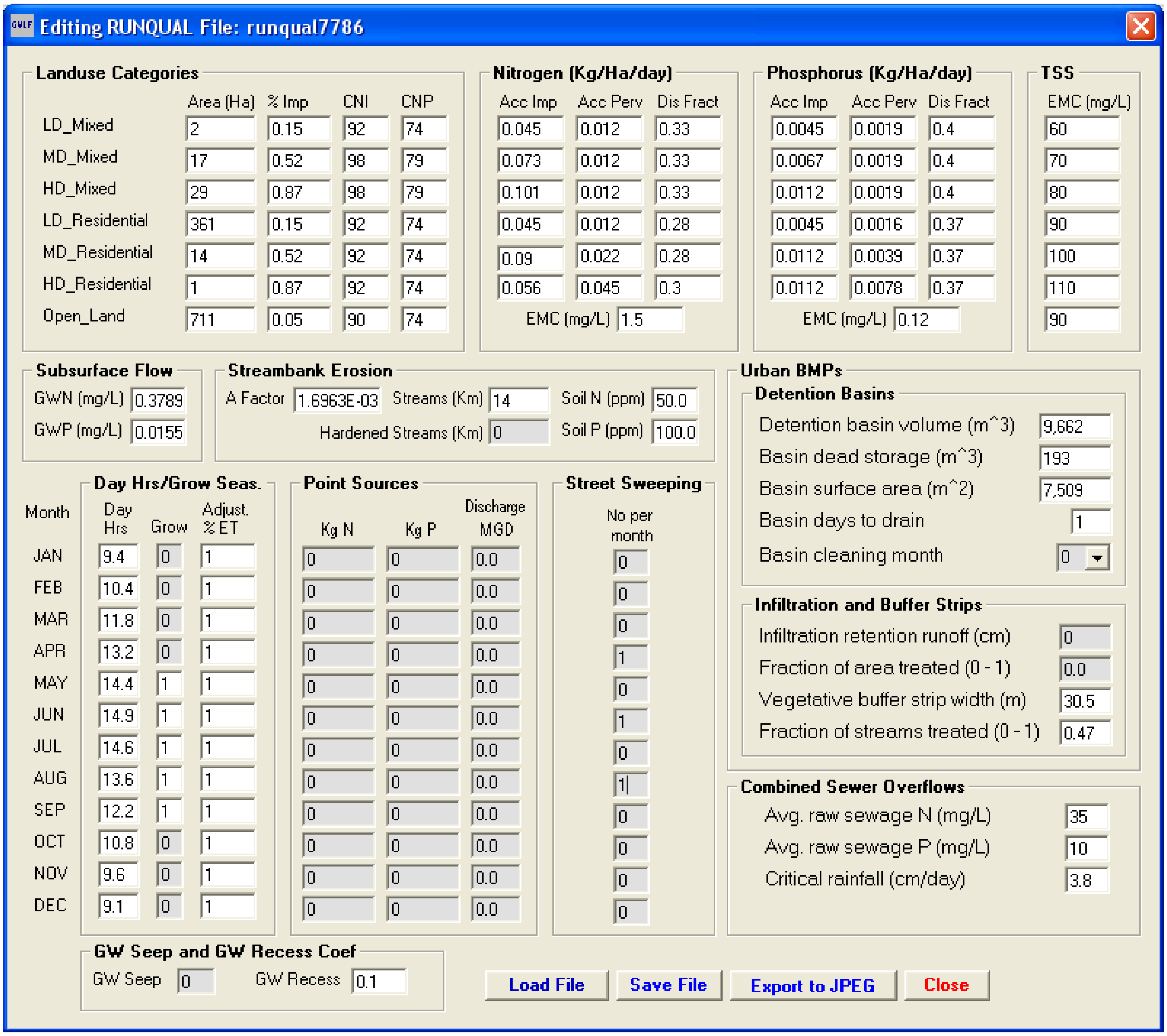
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Crouse - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Willow



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Landuse Categories / Nitrogen (Kg/Ha/day) / Phosphorus (Kg/Ha/day) / TSS

Landuse	Area (Ha)	% Imp	CNI	CNP	N Acc Imp	N Acc Perv	N Dis Fract	P Acc Imp	P Acc Perv	P Dis Fract	TSS EMC (mg/L)
LD_Mixed	2	0.15	92	74	0.045	0.012	0.33	0.0045	0.0019	0.4	60
MD_Mixed	17	0.52	98	79	0.073	0.012	0.33	0.0067	0.0019	0.4	70
HD_Mixed	29	0.87	98	79	0.101	0.012	0.33	0.0112	0.0019	0.4	80
LD_Residential	361	0.15	92	74	0.045	0.012	0.28	0.0045	0.0016	0.37	90
MD_Residential	14	0.52	92	74	0.09	0.022	0.28	0.0112	0.0039	0.37	100
HD_Residential	1	0.87	92	74	0.056	0.045	0.3	0.0112	0.0078	0.37	110
Open_Land	711	0.05	90	74	EMC (mg/L) 1.5			EMC (mg/L) 0.12			90

Subsurface Flow

GWN (mg/L) 0.3789
GWP (mg/L) 0.0155

Streambank Erosion

A Factor 1.6963E-03 Streams (Km) 14 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins

Detention basin volume (m^3)	9,662
Basin dead storage (m^3)	193
Basin surface area (m^2)	7,509
Basin days to drain	1
Basin cleaning month	0

Infiltration and Buffer Strips

Infiltration retention runoff (cm)	0
Fraction of area treated (0 - 1)	0.0
Vegetative buffer strip width (m)	30.5
Fraction of streams treated (0 - 1)	0.47

Combined Sewer Overflows

Avg. raw sewage N (mg/L)	35
Avg. raw sewage P (mg/L)	10
Critical rainfall (cm/day)	3.8

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 0.1

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RUNQUAL Data Input - Willow - Existing Conditions

RUNQUAL Hydrology for file: willowext-7786

Period of analysis: 24 years from 1975 to 1998

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
	Units in inches							
JAN	2.85	0.17	0.0	0.28	2.4	0.0	0.0	2.68
FEB	2.45	0.28	0.0	0.49	1.68	0.0	0.0	2.17
MAR	3.24	0.83	0.0	0.38	2.03	0.0	0.0	2.41
APR	3.01	1.73	0.0	0.14	1.14	0.0	0.0	1.28
MAY	3.85	3.07	0.0	0.11	0.76	0.0	0.0	0.87
JUN	4.11	4.16	0.0	0.15	0.15	0.0	0.0	0.3
JUL	4.33	4.73	0.0	0.18	0.0	0.0	0.0	0.18
AUG	3.76	3.82	0.0	0.11	0.0	0.0	0.0	0.11
SEP	3.45	2.53	0.0	0.1	0.82	0.0	0.0	0.92
OCT	2.61	1.41	0.0	0.12	1.08	0.0	0.0	1.2
NOV	3.2	0.73	0.0	0.19	2.28	0.0	0.0	2.48
DEC	3.0	0.33	0.0	0.32	2.35	0.0	0.0	2.67
Totals	39.86	23.77	0.0	2.58	14.7	0.0	0.0	17.28

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Willow – Existing Conditions

RUNQUAL Average Monthly Loads for file: willowext-7786

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	65434	586	759	25	44
FEB	68872	420	714	19	48
MAR	64906	507	732	22	45
APR	39308	282	366	12	22
MAY	28261	245	305	10	17
JUN	21714	136	211	6	14
JUL	18828	102	177	5	12
AUG	18776	110	164	5	11
SEP	32569	266	324	11	18
OCT	37625	288	358	12	21
NOV	59232	554	672	23	38
DEC	66886	577	771	25	46
Totals	522410	4075	5553	176	335

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Willow – Existing Conditions

RUNQUAL Hydrology for file: willowext-7786

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in)			Source Loads (Pounds)				
Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	5	2.4	75	4.8	4.8	0.3	0.3
MD_Mixed	42	12.8	4023	33.1	33.1	1.8	1.8
HD_Mixed	72	19.9	12251	15.3	15.3	0.8	0.8
LD_Residential	892	2.4	20317	735.4	735.4	37.3	37.3
MD_Residential	35	5.1	1853	29.5	29.5	2.0	2.0
HD_Residential	2	7.6	218	1.3	1.3	0.1	0.1
Open_Land	1757	1.6	58321		1539.5		123.2
Subsurface				3255.4	3255.4	133.2	133.2
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			425352		21.3		42.5
Totals	2805	2.6	522410	4075	5636	176	341

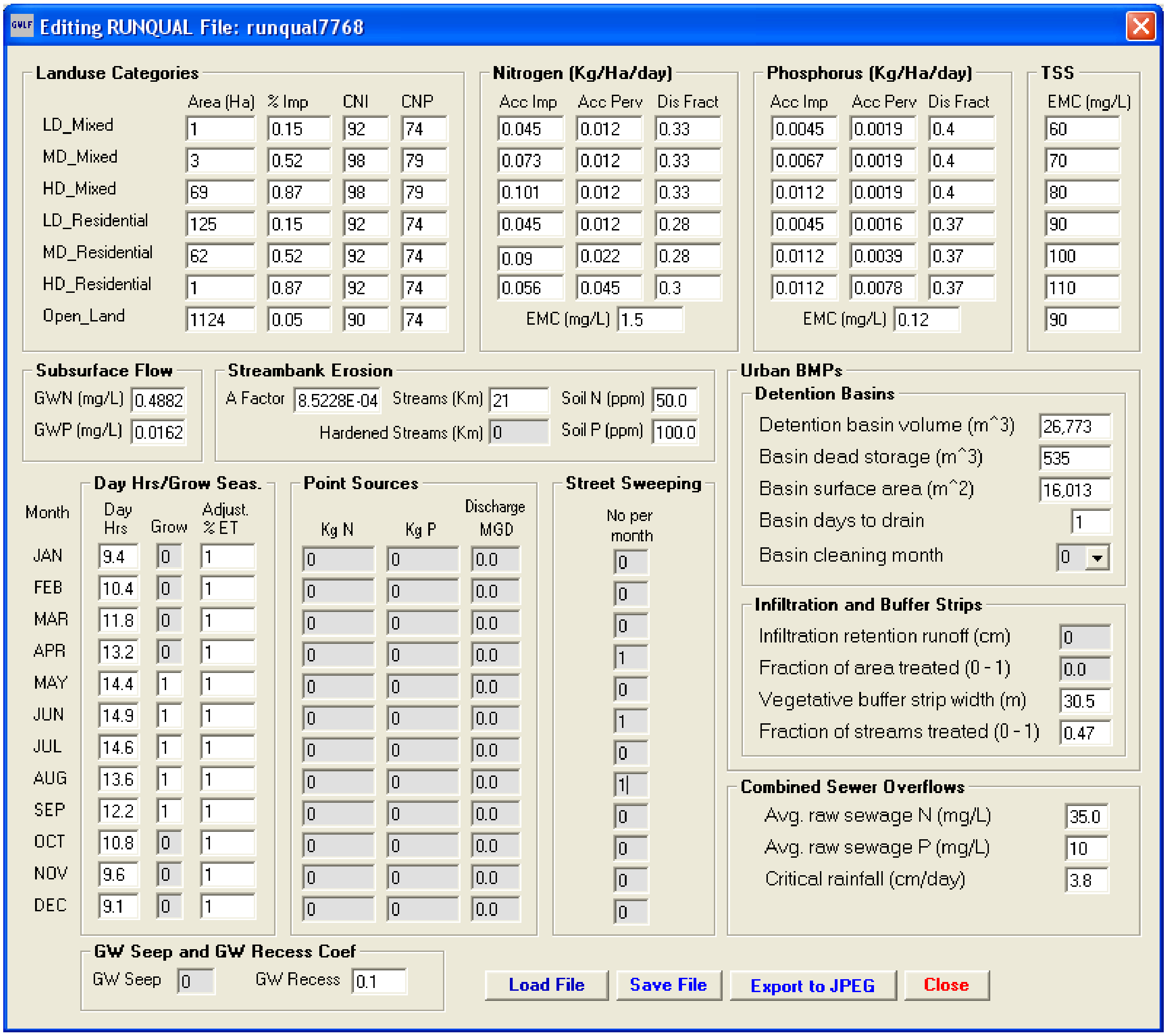
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Willow - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Montour



RUNQUAL Data Input - Montour - Existing Conditions

RUNQUAL Hydrology for file: montouext-7768

Period of analysis: 24 years from 1975 to 1998

Units in inches

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.85	0.15	0.0	0.3	2.39	0.0	0.0	2.69
FEB	2.45	0.26	0.0	0.51	1.68	0.0	0.0	2.19
MAR	3.24	0.78	0.0	0.41	2.05	0.0	0.0	2.46
APR	3.01	1.62	0.0	0.16	1.23	0.0	0.0	1.39
MAY	3.85	2.87	0.0	0.13	0.91	0.0	0.0	1.04
JUN	4.11	3.9	0.0	0.17	0.18	0.0	0.0	0.35
JUL	4.33	4.49	0.0	0.21	0.02	0.0	0.0	0.23
AUG	3.76	3.64	0.0	0.13	0.04	0.0	0.0	0.17
SEP	3.45	2.38	0.0	0.12	0.95	0.0	0.0	1.07
OCT	2.61	1.34	0.0	0.13	1.14	0.0	0.0	1.28
NOV	3.2	0.68	0.0	0.21	2.31	0.0	0.0	2.52
DEC	3.0	0.31	0.0	0.34	2.36	0.0	0.0	2.69
Totals	39.86	22.43	0.0	2.81	15.27	0.0	0.0	18.08

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Montour – Existing Conditions

RUNQUAL Average Monthly Loads for file: montouext-7768

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	64380	909	1197	31	58
FEB	73114	643	1127	23	65
MAR	67482	796	1175	27	62
APR	39919	472	621	16	31
MAY	29959	418	529	14	25
JUN	26253	249	390	8	22
JUL	24701	190	330	7	20
AUG	21811	207	305	7	16
SEP	32819	444	550	15	26
OCT	36916	471	594	16	28
NOV	57125	876	1078	29	50
DEC	66471	899	1217	31	61
Totals	540950	6576	9114	224	464

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Montour – Existing Conditions

RUNQUAL Hydrology for file: montouext-7768

Period of analysis: 24 years from 1975 to 1998

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
	Sources: Area (acres), Runoff (in)		**Source Loads (Pounds)**				
LD_Mixed	2	2.4	63	5.8	5.8	0.2	0.2
MD_Mixed	7	12.8	1172	14.1	14.1	0.5	0.5
HD_Mixed	171	19.9	48060	87.8	87.8	3.3	3.3
LD_Residential	309	2.4	11774	614.2	614.2	21.3	21.3
MD_Residential	153	5.1	13658	315.4	315.4	14.5	14.5
HD_Residential	2	7.6	363	3.0	3.0	0.1	0.1
Open_Land	2777	1.6	92198		2654.8		212.4
Subsurface				5535.5	5535.5	183.7	183.7
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			373663		18.7		37.4
Totals	3422	2.8	540950	6576	9249	224	473

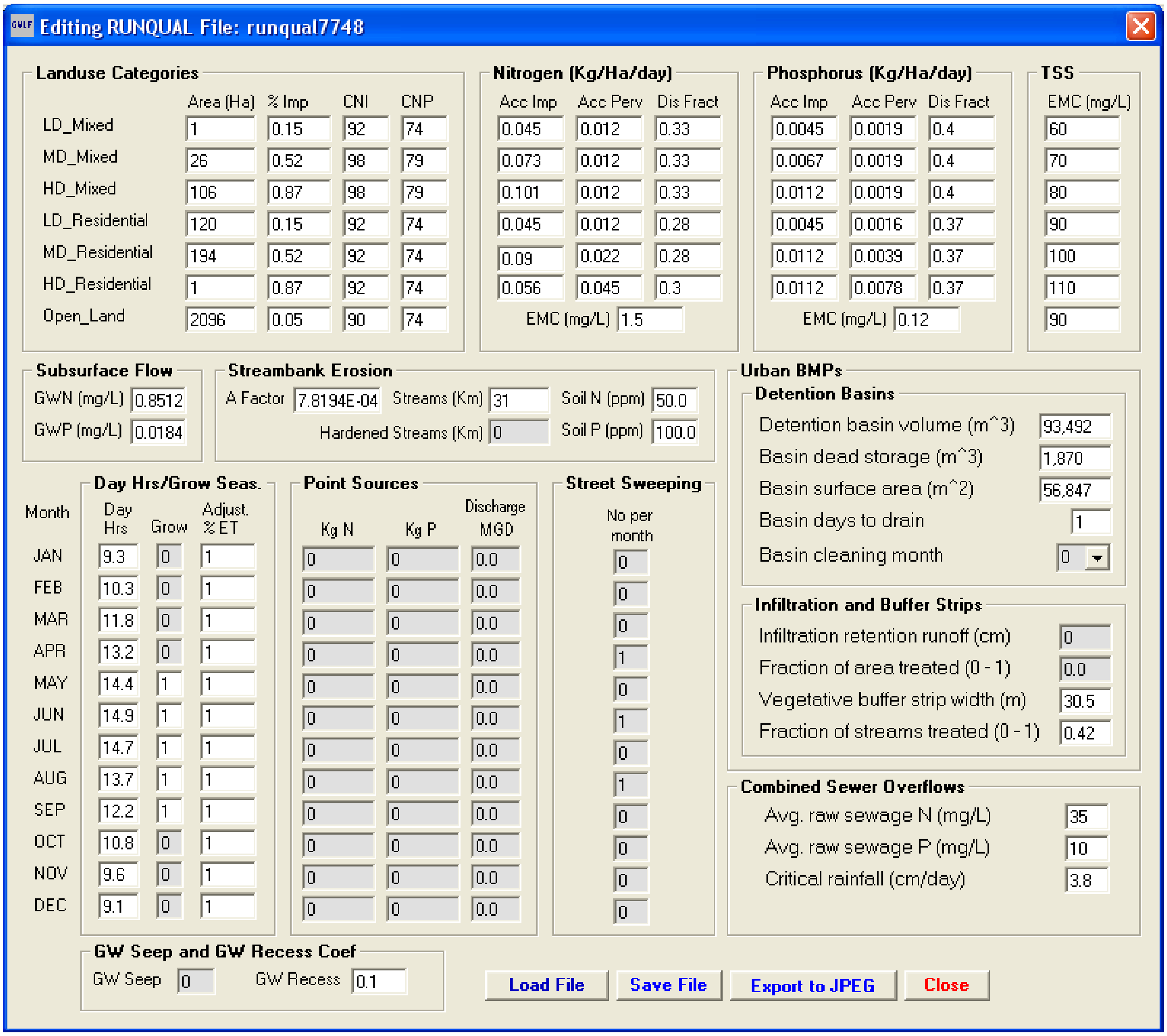
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Montour - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: North Fork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Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	1	0.15	92	74
MD_Mixed	26	0.52	98	79
HD_Mixed	106	0.87	98	79
LD_Residential	120	0.15	92	74
MD_Residential	194	0.52	92	74
HD_Residential	1	0.87	92	74
Open_Land	2096	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0.101	0.012	0.33
0.045	0.012	0.28
0.09	0.022	0.28
0.056	0.045	0.3

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.0045	0.0019	0.4
0.0067	0.0019	0.4
0.0112	0.0019	0.4
0.0045	0.0016	0.37
0.0112	0.0039	0.37
0.0112	0.0078	0.37

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
80
90
100
110
90

Subsurface Flow

GWN (mg/L) 0.8512
GWP (mg/L) 0.0184

Streambank Erosion

A Factor 7.8194E-04 Streams (Km) 31 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Day Hrs/Grow Seas. — Point Sources — Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.3	0	1	0	0	0.0	0
FEB	10.3	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.7	1	1	0	0	0.0	0
AUG	13.7	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 93,492
Basin dead storage (m^3) 1,870
Basin surface area (m^2) 56,847
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.42

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input - North Fork - Existing Conditions

RUNQUAL Hydrology for file: NFwonpext-7748

Period of analysis: 24 years from 1975 to 1998

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
	Units in inches							
JAN	2.85	0.15	0.0	0.31	2.39	0.0	0.0	2.7
FEB	2.45	0.25	0.0	0.52	1.68	0.0	0.0	2.2
MAR	3.24	0.75	0.0	0.42	2.07	0.0	0.0	2.49
APR	3.01	1.57	0.0	0.16	1.29	0.0	0.0	1.45
MAY	3.85	2.78	0.0	0.12	1.0	0.0	0.0	1.12
JUN	4.11	3.77	0.0	0.18	0.19	0.0	0.0	0.37
JUL	4.33	4.41	0.0	0.21	0.05	0.0	0.0	0.26
AUG	3.76	3.61	0.0	0.13	0.06	0.0	0.0	0.19
SEP	3.45	2.3	0.0	0.12	1.03	0.0	0.0	1.15
OCT	2.61	1.29	0.0	0.13	1.19	0.0	0.0	1.32
NOV	3.2	0.66	0.0	0.22	2.32	0.0	0.0	2.54
DEC	3.0	0.3	0.0	0.33	2.37	0.0	0.0	2.7
Totals	39.86	21.83	0.0	2.84	15.64	0.0	0.0	18.48

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – North Fork – Existing Conditions

RUNQUAL Average Monthly Loads for file: NFwonpext-7748

Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	126342	2902	3459	64	118
FEB	142336	2054	2974	47	129
MAR	132082	2560	3273	57	124
APR	78989	1575	1849	35	63
MAY	60159	1410	1615	31	52
JUN	53708	878	1145	19	45
JUL	48697	647	910	14	40
AUG	42765	696	880	15	33
SEP	65165	1485	1683	32	53
OCT	73118	1552	1782	34	58
NOV	112251	2823	3208	62	101
DEC	128640	2887	3474	64	120
Totals	1064252	21470	26251	475	935

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – North Fork – Existing Conditions

RUNQUAL Hydrology for file: NFwonpext-7748

Period of analysis: 24 years from 1975 to 1998

Sources: Area (acres), Runoff (in) — Source Loads (Pounds)

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
LD_Mixed	2	2.4	65	9.6	9.6	0.2	0.2
MD_Mixed	64	12.8	10492	202.1	202.1	4.7	4.7
HD_Mixed	262	19.9	76251	223.2	223.2	5.2	5.2
LD_Residential	297	2.4	11672	975.9	975.9	20.7	20.7
MD_Residential	479	5.1	44133	1633.3	1633.3	46.1	46.1
HD_Residential	2	7.6	374	5.0	5.0	0.1	0.1
Open_Land	5179	1.6	171928		5004.9		400.4
Subsurface				18420.7	18420.7	398.2	398.2
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			749338		37.5		74.9
Totals	6286	2.8	1064252	21470	26512	475	951

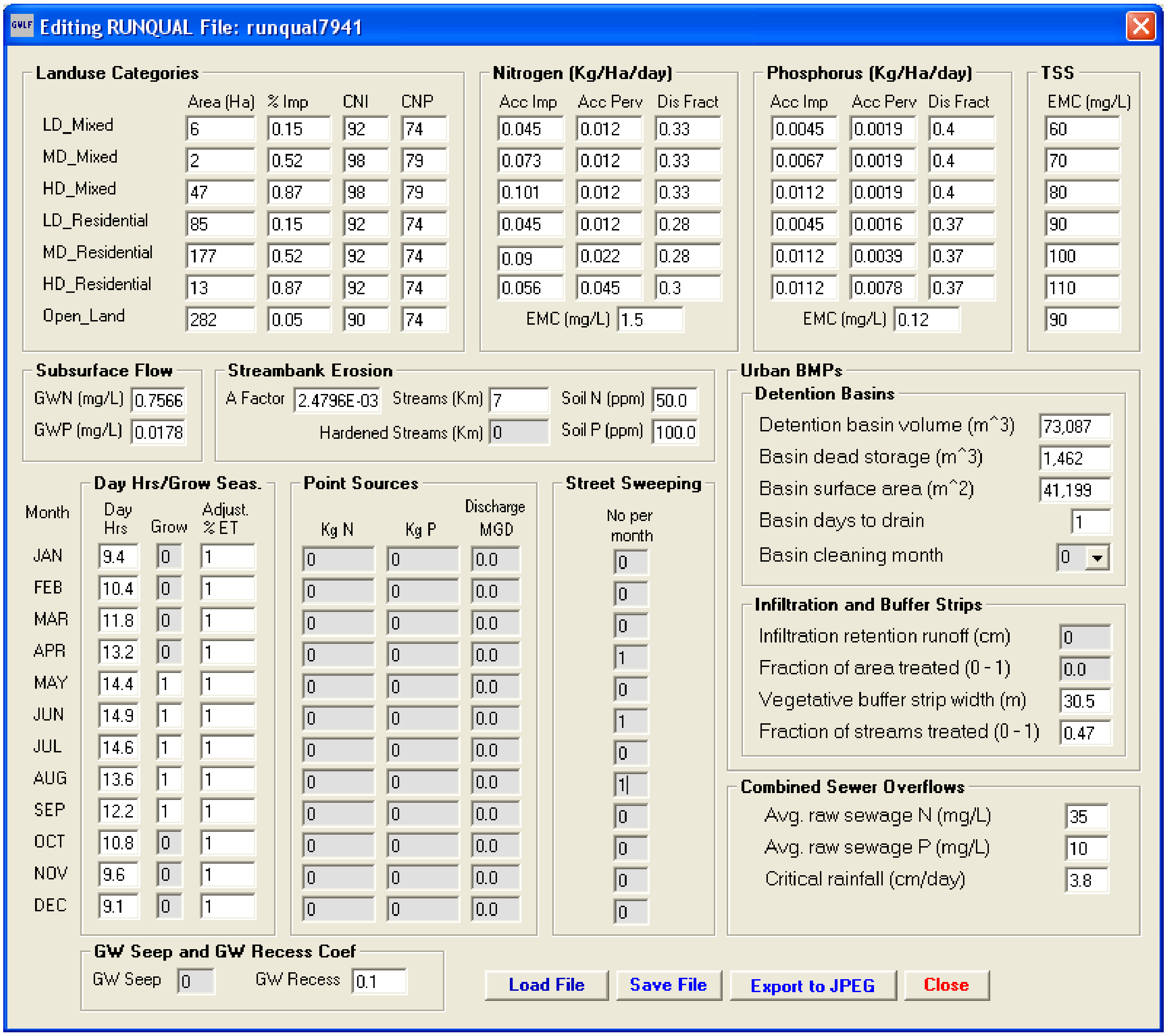
Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - North Fork - Existing Conditions

Modeling Results

Existing Conditions

Subbasin: Fish Run



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Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	6	0.15	92	74
MD_Mixed	2	0.52	98	79
HD_Mixed	47	0.87	98	79
LD_Residential	85	0.15	92	74
MD_Residential	177	0.52	92	74
HD_Residential	13	0.87	92	74
Open_Land	282	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0.101	0.012	0.33
0.045	0.012	0.28
0.09	0.022	0.28
0.056	0.045	0.3

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.0045	0.0019	0.4
0.0067	0.0019	0.4
0.0112	0.0019	0.4
0.0045	0.0016	0.37
0.0112	0.0039	0.37
0.0112	0.0078	0.37

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
80
90
100
110
90

Subsurface Flow

GWN (mg/L) 0.7566
GWP (mg/L) 0.0178

Streambank Erosion

A Factor 2.4796E-03 Streams (Km) 7 Soil N (ppm) 50.0
Hardened Streams (Km) 0 Soil P (ppm) 100.0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 73,087
Basin dead storage (m^3) 1,462
Basin surface area (m^2) 41,199
Basin days to drain 1
Basin cleaning month 0

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0
Fraction of area treated (0 - 1) 0.0
Vegetative buffer strip width (m) 30.5
Fraction of streams treated (0 - 1) 0.47

Day Hrs/Grow Seas. / Point Sources / Street Sweeping

Month	Day Hrs	Grow	Adjust. % ET	Kg N	Kg P	Discharge MGD	No per month
JAN	9.4	0	1	0	0	0.0	0
FEB	10.4	0	1	0	0	0.0	0
MAR	11.8	0	1	0	0	0.0	0
APR	13.2	0	1	0	0	0.0	1
MAY	14.4	1	1	0	0	0.0	0
JUN	14.9	1	1	0	0	0.0	1
JUL	14.6	1	1	0	0	0.0	0
AUG	13.6	1	1	0	0	0.0	1
SEP	12.2	1	1	0	0	0.0	0
OCT	10.8	0	1	0	0	0.0	0
NOV	9.6	0	1	0	0	0.0	0
DEC	9.1	0	1	0	0	0.0	0

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35
Avg. raw sewage P (mg/L) 10
Critical rainfall (cm/day) 3.8

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 0.1

Load File | Save File | Export to JPEG | Close

RUNQUAL Data Input - Fish Run - Existing Conditions

RUNQUAL Hydrology for file: Fishext-7941

Period of analysis: 24 years from 1975 to 1998

Units in inches

Month	Prec	ET	Extracted Water	Runoff	Subsurface Flow	Point Src Flow	CSO Flow	Stream Flow
JAN	2.56	0.17	0.0	0.46	1.93	0.0	0.0	2.39
FEB	2.28	0.28	0.0	0.48	1.52	0.0	0.0	2.0
MAR	3.11	0.78	0.0	0.48	1.85	0.0	0.0	2.33
APR	2.96	1.58	0.0	0.25	1.14	0.0	0.0	1.38
MAY	3.68	2.77	0.0	0.19	0.82	0.0	0.0	1.01
JUN	4.03	3.73	0.0	0.27	0.15	0.0	0.0	0.42
JUL	3.92	4.22	0.0	0.31	0.0	0.0	0.0	0.31
AUG	3.41	3.45	0.0	0.21	0.01	0.0	0.0	0.23
SEP	3.23	2.18	0.0	0.18	0.87	0.0	0.0	1.05
OCT	2.31	1.22	0.0	0.16	0.94	0.0	0.0	1.1
NOV	3.03	0.61	0.0	0.33	2.09	0.0	0.0	2.42
DEC	2.81	0.29	0.0	0.4	2.12	0.0	0.0	2.52
Totals	37.31	21.27	0.0	3.72	13.42	0.0	0.0	17.14

Monthly Loads | Export to JPEG | Print | Close

Hydrologic and Hydraulic Results – Fish Run – Existing Conditions

RUNQUAL Average Monthly Loads for file: Fishext-7941

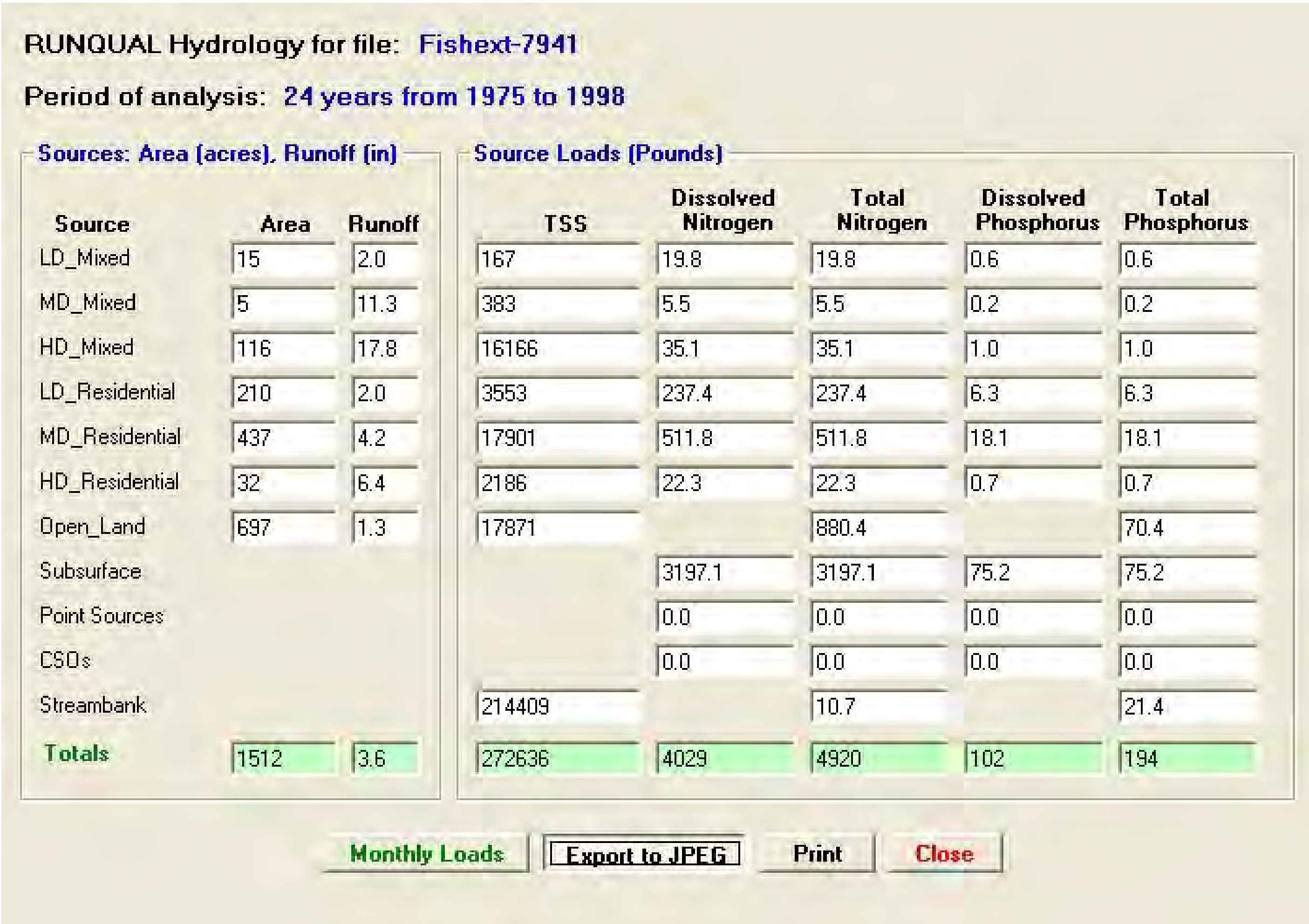
Period of analysis: 24 years from 1975 to 1998

TSS and Nutrient Loads (Pounds)

Month	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
JAN	32841	506	617	13	24
FEB	31710	401	516	11	22
MAR	32414	492	601	13	24
APR	21294	300	358	7	14
MAY	16079	255	296	6	11
JUN	14551	145	200	4	9
JUL	11152	114	160	3	8
AUG	12175	155	198	4	8
SEP	18538	295	337	7	12
OCT	17963	268	306	7	11
NOV	31006	545	624	13	22
DEC	32913	554	651	14	24
Totals	272636	4029	4862	102	190

Hydrology | Loads by Source | Export to JPEG | Print | Close

Average Monthly Loads – Fish Run – Existing Conditions



RUNQUAL Hydrology for file: Fishext-7941

Period of analysis: 24 years from 1975 to 1998

Source	Area	Runoff	TSS	Dissolved Nitrogen	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus
	Sources: Area (acres), Runoff (in)		Source Loads (Pounds)				
LD_Mixed	15	2.0	167	19.8	19.8	0.6	0.6
MD_Mixed	5	11.3	383	5.5	5.5	0.2	0.2
HD_Mixed	116	17.8	16166	35.1	35.1	1.0	1.0
LD_Residential	210	2.0	3553	237.4	237.4	6.3	6.3
MD_Residential	437	4.2	17901	511.8	511.8	18.1	18.1
HD_Residential	32	6.4	2186	22.3	22.3	0.7	0.7
Open_Land	697	1.3	17871		880.4		70.4
Subsurface				3197.1	3197.1	75.2	75.2
Point Sources				0.0	0.0	0.0	0.0
CSOs				0.0	0.0	0.0	0.0
Streambank			214409		10.7		21.4
Totals	1512	3.6	272636	4029	4920	102	194

Monthly Loads | Export to JPEG | Print | Close

Pollution Loading by Source - Fish Run - Existing Conditions

Appendix 4 – Center for Watershed Protection's 2007 *Urban Stormwater Retrofit Practices*, Appendix B: Defining Retrofit Pollutant Load Reduction

Appendix B: Defining Retrofit Pollutant Load Reduction

I. The Simple Method

The Simple Method estimates the annual pollutant load exported in stormwater runoff from small urban catchments (Schueler, 1987). The Simple Method sacrifices some precision for the sake of simplicity and ease of use, but is a reasonably accurate way to predict the pollutant load reduced by individual stormwater retrofits. The annual pollutant load exported in pounds per year from the contributing drainage area to a retrofit can be determined by solving the equation provided in Table B.1. Each of the terms in the equation can be extracted from data contained in a retrofit concept design.

Depth of Rainfall (P)

P represents the depth of precipitation that falls on the contributing drainage area of the retrofit site during the course of a normal year. Annual rainfall data for select U.S. cities can be obtained from Table 1.2 or derived from local rainfall gages with reliable, long-term (> 20 years) records.

Correction Factor (P_j)

Some of the storms that occur during a given year are so minor that they generate no stormwater runoff. The rainfall from these small storms produce is stored in surface depressions and either evaporates into the air or infiltrates into the ground. To account for these storms, the correction factor (P_j) is used. The design team can analyze local rainfall-runoff patterns to determine the value of P_j or simply use prior analyses from the Washington DC area that indicate Pj is approximately 10% of the annual rainfall depth (Schueler, 1987). The default value for P_j should be 0.9 unless local rainfall-runoff analyses are available.

Runoff Coefficient (R_v)

The runoff coefficient (R_v) is a useful measure of a development site's response to rainfall events. In theory, it is calculated using the equation provided in Table B.2.

Table B.1: Pollutant Load Export Equation
$L = [(P)(Pj)(Rv) \div (12)^a](C)(A)(2.72)^a$
Where: L = Average annual pollutant load (pounds) P = Average annual rainfall depth (inches) P_j = Fraction of rainfall events that produce runoff R_v = Runoff coefficient, which expresses the fraction of rainfall that is converted into runoff C = Event mean concentration of the pollutant in urban runoff (mg/l) A = Area of the contributing drainage (acres)
[a] 12 and 2.72 are unit conversion factors

Table B.2: The Runoff Coefficient
$R_v = R/P$ Where: R = Volume of storm runoff (watershed-inches) P = Volume of storm rainfall (watershed-inches)

The designer is trying to solve the equation for R and does not know the value of R_V. A study of rainfall/runoff relationships for many small watersheds across the U.S. showed that R_V has a distinctly linear relationship with impervious cover (Schueler, 1987). The runoff coefficient increases in direct proportion to the percent impervious cover (I) present in a catchment. The resulting equation shown in Table B.3 can be used to estimate R_V for the contributing drainage area to a retrofit site.

Site Area (A)

The contributing drainage area (A, in acres) can be directly obtained from the drainage area provided in the retrofit concept plan.

Table B.3: Calculating the Runoff Coefficient
$R_v = 0.05 + 0.009(I)$ Where: I = The amount of impervious cover on the site, expressed as a percentage of the total site area. "I" should be expressed as a whole number within the equation (i.e. a site that is 75% impervious would use I = 75 when calculating R_v)

Pollutant Concentration (C)

The last input data needed is the event mean concentration (EMC) of the stormwater pollutant of concern (C) for the retrofit site. Ideally, local stormwater quality monitoring data would be used to define the value of C, although such data may not be available. As an alternative, designers can consult national stormwater quality monitoring databases that define event mean concentration statistics derived from a large population of runoff monitoring samples. The National Stormwater Quality Database (NSQD) is an extremely helpful tool to define expected EMCs for a wide range of different stormwater pollutants (Pitt *et al.,* 2004). Table B.4 summarizes EMCs for more than 20 common stormwater pollutants in runoff from residential, commercial, industrial, roadway and open space land uses. An updated NSQD is scheduled for release in late 2007.

Some designers may want to choose an alternative EMC value to represent a particular stormwater hotspot or because an on-site retrofit serves a single urban source area. While much less monitoring data is available to characterize hotspot runoff, some of the published data significantly depart from the EMC values predicted by the NSQD. Designers may wish to consult Table B.5 in these situations.

<u>Proper Use of the Simple Method</u>

Several caveats should be observed when applying the Simple Method:

- The Simple Method provides an estimate of the stormwater pollutant load exported from individual retrofit sites less than one square mile in area. More sophisticated water quality simulation models are needed to analyze larger drainage areas.
- It is important to remember that the Simple Method do not represent the total pollutant load exported from a retrofit site, particularly when the contributing drainage area is large enough to generate

appreciable baseflow. The baseflow pollutant load can safely be neglected at the scale of a retrofit site, until the contributing drainage area exceeds about a hundred acres. For example, in a large, sparsely developed subwatershed (e.g. impervious cover of less than 5%), as much as 75% of the annual storm water runoff volume may occur as baseflow instead of surface runoff (Schueler, 1987). In this case, the pollutant load carried by baseflow may be equivalent to the amount of pollution carried by surface runoff.

Table B.4: Summary of Pollutant EMCs in Stormwater Runoff

	All Data	Residential	Commercial	Industrial	Freeways	Open Space
# of Storms Sampled	*3,765*	*1,042*	*527*	*566*	*185*	*49*
Median Event Mean Concentrations (mg/L or ppm, except where noted)						
TDS	80	72	72	86	77.5	125
TSS	59	49	43	81	99	48.5
BOD_5	8.6	9.0	11.0	9.0	8.0	5.4
COD	53	54.5	58	58.6	100	42.1
Fecal Coliform[1]	5,091	7,000	4,600	2,400	1,700	7,200
NO2 + NO3	0.60	0.60	0.6	0.69	0.28	0.59
TKN	1.4	1.5	1.5	1.4	2.0	0.74
Total N	2.0	2.1	2.1	2.09	2.28	1.33
Dissolved P	0.13	0.18	0.11	0.10	0.20	0.13
Total P	0.27	0.31	0.22	0.25	0.25	0.31
Dissolved Cu[2]	8.0	7.0	7.57	8.0	10.9	--
Total Cu[2]	16	12	17	20.8	34.7	10
Dissolved Zn[2]	52	31.5	59	112	51	--
Total Zn[2]	116	73	150	199	200	40

Source: Pitt *et al.*, 2004.
[1] MPN/100 mL, which represents the most probable number (MPN) of bacteria that would be found in 100 mL of water
[2] Cu and Zn values are shown in μg/l

Table B.5: Summary of Pollutant EMCs Associated with Stormwater Hotspots						
	TSS	Total P	Total N	Fecal Coliform[1]	Total Cu[2]	Total Zn[2]
Land Use	Median Event Mean Concentrations (mg/L or ppm, except where noted)					
Lawns	602	2.1	9.1	2,400	17	50
Landscaping	37	--	--	9,400	94	263
Residential Roof	19	0.11	1.5	26	200	312
Commercial Roof	9	0.14	2.1	110	7	256
Industrial Roof	17	--	--	580	62	1390
Res/Comm Parking Lot	27	0.15	1.9	180	51	139
Industrial Parking Lot	228	--	--	270	34	224
Driveway	173	0.56	2.1	1,700	17	107
Local Residential Street	172	0.55	1.4	3,700	25	173
Commercial Street	468	--	--	1,200	73	450
Gas Station	31	--	--	--	88	290
Auto Recycler	335	--	--	--	103	520
Heavy Industry	124	--	--	--	148	1600

Sources: Claytor *et al.,* 1996; Steuer *et al.,* 1997; Bannerman, 1993; and Waschbuch, 2000.
[1] MPN/100 mL, which represents the most probable number (MPN) of bacteria that would be found in 100 mL of water
[2] Cu and Zn values are shown in μg/l

II. Calculating Pollutant Loads and Pollutant Load Reduction

Pollutant load reduction by individual stormwater retrofits is computed in a six-step process, as shown in Table B.6, and described below:

Step 1: Calculate CDA Impervious Cover

This step calculates the impervious cover (I) present in the drainage area contributing to the proposed retrofit. Operationally, impervious cover is defined as any hard surface in the catchment that cannot infiltrate rainfall, such as rooftops, roads, sidewalks, driveways and any other compacted gravel or dirt surfaces. As a general rule, man-made surfaces that are not vegetated should be considered impervious. Chapter 4.3 describes the methods used to measure or estimate impervious cover in the retrofit contributing drainage area (Cappiella and Brown, 2001). Unless upland restoration practices remove or disconnect impervious cover in the contributing drainage area, impervious cover before and after the retrofit will be the same.

Step 2: Calculate Pre-Retrofit Pollutant Load

The second step computes the pollutant load exported from the drainage area prior to the retrofit using the equation shown in Table B.7.

Step 3: Identify the Stormwater Retrofit

This step identifies the stormwater treatment option(s) that will be applied to the retrofit site, which can be taken directly from the retrofit concept design.

Table B.6: Process for Calculating Pre- and Post-Retrofit Pollutant Loads	
Step	Task
1	Calculate Site Imperviousness
2	Calculate the Pre-Retrofit Pollutant Load
3	Identify the Stormwater Retrofit
4	Determine the Retrofit Pollutant Removal Efficiency
5	Calculate the Post-Retrofit Pollutant Load
6	Calculate the Pollutant Load Reduction of the Retrofit

Table B.7: Method for Calculating Pre-Retrofit Pollutant Loading

$L_{pre} = [(P)(Pj)(Rv)/12^{a}](C)(A)(2.72)^{a}$

Where:
L_{pre} = Average annual pollutant load exported from the site prior to stormwater retrofitting (pounds)
P = Average annual rainfall depth (inches)
P_j = Fraction of rainfall events that produce runoff
R_v = Runoff coefficient
C = Event mean concentration of the pollutant in urban runoff (mg/l)
A = Area of the contributing drainage area (acres)

[a] 12 and 2.72 are unit conversion factors

Step 4: Use the Design Point Method to Determine Retrofit Pollutant Removal Efficiency

Median pollutant removal rates for each stormwater treatment option are presented in Chapter 3. These rates need to be adjusted to account for site-specific factors and design features than can enhance or reduce their pollutant removal rates using the design point method. The method consists of a series of tables that award or deduct points for certain site-specific conditions and design factors present at the individual retrofit site. The designer selects the appropriate design point table for the stormwater treatment option they plan to use, reviews the proposed retrofit design and computes a total retrofit design score. If the design score is positive, the removal rate for the pollutant of concern is increased using the equation provided in Table B.8. If the retrofit score is negative, the removal rate is reduced using the equation provided in Table B.9.

The example provided in Box B.1 illustrates the use of the design point method on a hypothetical retrofit site. Note that the net design score excludes the design factors that only influence phosphorus removal, while the net phosphorus score includes them. The designer should use the net phosphorus score to adjust the phosphorus removal rate and the net design score to adjust the removal rates for all other pollutants.

Table B.8: Adjusting Removal Rates for Retrofits with a Positive Design Score

Adjusted RR = Median RR + [(DS ÷ 5) * (High End RR – Median RR)]

Where:
RR = Removal rate (%)
DS = Design score

Note: A maximum of five positive design points is allowed

Table B.9: Adjusting Removal Rates for Retrofits with a Negative Design Score

Adjusted RR = Median RR + [(DS ÷ 5) * (Median RR – Low End RR)]

Where:
RR = Removal rate (%)
DS = Design score

Note: A maximum of five negative design points is allowed

Box B.1: Applying the Design Point Method

A bioretention retrofit is being proposed to serve a contributing drainage area that is one acre in size and 35% impervious. After review of the retrofit concept design, the designer awards the following points for the project:

Negative Factors that Reduce Removal Rates

- Does not provide full WQ_v, due to space constraints
- Filter bed less than 18 inches deep, due to limited available head
- Single cell design, due to space constraints
- Underdrain needed, to address cold climate conditions and impermeable soils

Positive Factors that Enhance Removal Rates

- Filter media soil P-Index less than 30, to enhance phosphorus removal
- Upflow pipe on underdrain, to enhance nitrogen removal

Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested filter media soil P Index less than 30 (phosphorus only)	X	+ 3
Filter bed deeper than 30 inches		+ 1
Two cell design with pretreatment		+ 1
Permeable soils; no underdrain needed		+ 2
Upflow pipe on underdrain	X	+1
Impermeable soils; underdrain needed	X	- 1
Filter bed less than 18 inches deep	X	- 1
Single cell design	X	- 1
Bioretention cell is less than 5% of CDA		-1
Does not provide full water quality storage volume	X	- 2
Filter media not tested for P Index (phosphorus only)		- 3
NET DESIGN SCORE (max of 5 points)		**- 4**
NET PHOSPHORUS SCORE		**- 1**

Since both design scores are negative (-4 and -1), the median pollutant removal rates are decreased using the equation provided in Table B.9. The adjusted removal rates for the retrofit are shown below:

Total Suspended Solids	24%	Bacteria	26%
Total Phosphorus	-11%	Hydrocarbons	82%
Total Nitrogen	41%	Chloride	0%
Total Zinc	48%	Trash/Debris	82%
Total Copper	48%		

The example shows why it is so important to maximize site and design factors to enhance the pollutant removal performance of the retrofit. In many cases, the designer may revise their concept design to include design features that can attain a higher net design point score.

Step 5: Calculate Post-Retrofit Pollutant Load

This step calculates the pollutant load exported from the drainage area contributing to the retrofit using the equation shown in Table B.10.

Step 6: Calculate the Pollutant Load Reduction of the Retrofit

The final step calculates the pollutant load reduced by the proposed stormwater retrofit, which is simply the post-retrofit pollutant load, subtracted from the pre-retrofit pollutant load (Table B.11).

Table B.10: Method for Calculating Post-Retrofit Pollutant Loading
$L_{post} = L_{pre} * [1 - (RR)]$
Where: L_{post} = Annual pollutant load exported from the site after stormwater retrofit (pounds/yr)
RR = Adjusted removal rate (%) calculated in Step 4
L_{pre} = Annual pollutant load exported from the site before the stormwater retrofit (pounds/year)

Table B.11: Method for Calculating the Pollutant Load Reduction of the Retrofit
$LR = L_{post} - L_{pre}$
Where: LR = Annual pollutant load removed by the proposed retrofit (pounds/year)
L_{post} = Annual pollutant load exported from the site after stormwater retrofitting (pounds/year)
L_{pre} = Annual pollutant load exported from the site prior to stormwater retrofitting (pounds/year)

III. Design Point Tables

This section presents the design point tables for seven stormwater treatment options.

1. ED Retrofits		
Design Factors	*X*	*Points*
Wet ED or Multiple Cell Design		+ 2
Exceeds target WQv by more than 25%		+ 1
Exceeds target WQv by more than 50%		+ 2
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay		+ 1
Constructed wetland elements included in design		+ 1
On-line design		- 1
Flow path less than 1:1		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max. of 5 points)		

2. Wet Pond Retrofits		
Design Factors	*X*	*Points*
Wet ED or Multiple Pond Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Exceeds target WQv by more than 25%		+ 1
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay at major outfalls		+ 1
Wetland elements cover at least 10% of surface area		+ 1
Single cell pond		- 1
Flow path less than 1:1		- 1
On-line design		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max of 5 points)		

3. Wetland Retrofits		
Design Factors	*X*	*Points*
Pond-Wetland or Multiple Cell Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Complex wetland microtopography		+ 2
Exceeds target WQv by more than 25%		+ 1
Flow path greater than 1.5 to 1		+ 1
Wooded wetland design		+ 1
Off-line design		+ 1
No forebay or pretreatment features		- 1
Wetland intersects with groundwater		- 1
Flow path is less than 1:1		- 1
No wetland planting plan specified		- 2
Wetland SA to CDA ratio is less than 1.5%		- 2
Does not provide full WQv volume		- 2
NET DESIGN SCORE (max of 5 points)		

4. Bioretention Retrofits		
Design Factors	*X*	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested filter media soil P Index less than 30 (phosphorus only)		+ 3
Filter bed deeper than 30 inches		+ 1
Two cell design with pretreatment		+ 1
Permeable soils; no underdrain needed		+ 2
Upflow pipe on underdrain		+1
Impermeable soils; underdrain needed		- 1
Filter bed less than 18 inches deep		- 1
Single cell design		- 1
Bioretention cell is less than 5% of CDA		-1
Does not provide full water quality storage volume		- 2
Filter media not tested for P Index (phosphorus only)		- 3
NET DESIGN SCORE (max of 5 points)		
NET PHOSPHORUS SCORE (max of 5 points)		

5. Filtering Retrofits		
Design Factors	*X*	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Site is a severe or confirmed hotspot		+ 2
Organic media used within filter bed (all pollutants except N/P)		+ 2
Two cells with at least 25% WQv allocated to pretreatment		+ 1
Filter bed SA is at least 2.5% of CDA		+ 1
Filter bed exposed to sunlight		+ 1
Off-line design w/ storm bypass		+ 1
Dry pretreatment		- 1
On-line design, w/o storm bypass		- 1
Underground design (except MCTT)		- 1
Filter design is hard to access for maintenance		- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		

6. Infiltration Retrofits		
Design Factors	**X**	**Points**
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested infiltration rates between 1.0 and 4.0 in/hr		+ 2
At least two forms of pretreatment prior to infiltration		+ 2
CDA is nearly 100% impervious		+ 1
Off-line design w/ cleanout pipe		+ 1
Underdrain utilized		- 1
Filter fabric used on trench bottom		- 1
CDA more than 1.0 acre		- 1
Soil infiltration rates < 1.0 in/hr or > 4.0 in/hr		- 2
Pervious areas or construction clearing in CDA		- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		

7. Swale Retrofits		
Design Factors	*X*	***Points***
Exceeds target WQv by more than 50%		+ 3
Dry or wet swale design		+ 2
Exceeds target WQv by more than 25%		+ 2
Longitudinal swale slope between 0.5 to 2.0%		+ 1
Velocity within swale < 1 fps during WQ storm		+ 1
Measured soil infiltration rates exceed 1.0 in/hr		+ 1
Multiple cells with pretreatment		+ 1
Off-line design w/ storm bypass		+ 1
Longitudinal swale slope < 0.5% or > 2%		- 1
Measured soil infiltration rates less than 1.0 in/hr		- 1
Swale sideslopes more than 5:1 h:v		- 1
Swale intersects groundwater (except wet swale)		- 1
No pretreatment to the swale or channel		- 1
Swales conveys stormflows up to 10 year storm		- 2
Does not provide full WQv volume		- 2
Grass channel		- 3
NET DESIGN SCORE (max of 5 points)		

Appendix 5 – Center for Watershed Protection's 2007 *Urban Stormwater Retrofit Practices*, Appendix D: Retrofit Pollutant Removal Rates

Appendix D: Retrofit Pollutant Removal Rates

I. Basic Approach

This appendix documents how the pollutant removal rates for the stormwater treatment options presented in Chapter 3 were derived. The basic approach used to derive the pollutant removal rates was to update the National Pollutant Removal Performance Database (Winer, 2000) with new performance studies published in the last five years. The updated database was then statistically analyzed to derive new median and quartile values for each major group of stormwater treatment practices. The low end and high end are the 25th and 75th quartiles, respectively. Also, removal rates were rounded to the nearest 5 % for ease of use.

Where data gaps remained, engineering judgment was used to derive pollutant removal rates as described in Section II. These removal rates are indicated by **bold type** in the ensuing tables and designers should regard them as a provisional estimate until additional pollutant removal performance data becomes available. The notes section of the tables can provide more information on these derived rates.

II. Documentation of Pollutant Removal Rates

Recurring data gaps existed for organic carbon, hydrocarbons, chlorides, trash/debris and, for some practices, bacteria. The particular assumptions to derive removal rates for these pollutants are summarized below.

- *Organic Carbon* – Organic carbon is used to describe all total organic carbon, BOD or COD removal data contained in the original database (Winer, 2000). Very little new monitoring data was available, so the medians and quartiles were re-computed from the 2000 database.
- *Hydrocarbons* - Previous studies have found that the ability of stormwater treatment practices to remove petroleum hydrocarbons is closely related to their ability to remove suspended solids (Winer, 2000). This is due to the fact that hydrocarbons quickly adsorb to sediment particles and organic matter suspended in stormwater runoff (Schueler and Shepp, 1993). Consequently, hydrocarbon removal was assumed to be generally comparable to total suspended solids removal.
- *Chlorides* - Because chloride is extremely soluble, it is very difficult to remove from stormwater runoff. A review of 10 performance monitoring studies in cold climate regions failed to find any instance of positive removal rates for chlorides for any stormwater treatment practice. Indeed, many practices actually had negative removal rates. It was therefore assumed that chloride removal rates would be zero for all stormwater treatment options.
- *Trash/Debris* – No performance monitoring data were available to define removal rates for trash and debris. It was assumed that the pollutant removal mechanisms for trash and debris are similar to those used to remove total suspended solids (e.g. gravitational settling, screening). One key difference is that some materials float on the

surface, although most would still be trapped in the stormwater practice unless there was a major overflow. It was therefore assumed that trash and debris removal rates would be equal or slightly greater than the suspended solids removal rate for most stormwater practices.

Table D.1: Range of Reported Removal Rates for Dry Extended Detention Ponds			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	20	50	70
Total Phosphorus	15	20	25
Soluble Phosphorus	-10	-5	10
Total Nitrogen	5	25	30
Organic Carbon	15	25	35
Total Zinc	0	30	60
Total Copper	20	30	40
Bacteria	**25**	**35**	**50**
Hydrocarbons	**40**	**70**	**80**
Chloride	**0**	**0**	**0**
Trash/Debris	**65**	**80**	**85**

Notes: Ten monitoring studies evaluated the performance of dry ED ponds for most parameters. Only two monitoring studies were available on **bacteria removal rates** for dry extended detention ponds, so engineering judgment was needed to establish the final removal rates. The primary mechanisms that facilitate bacteria removal are exposure to UV light and gravitational settling (Schueler, 1999). These removal mechanisms have been documented for wet ponds, which have been more extensively monitored for bacteria removal in wet ponds. Since stormwater runoff is not retained within dry ED ponds for as long as wet ponds, settling times and exposure to UV light are reduced. Dry ED ponds also have a greater risk of sediment resuspension than wet ponds, which can reintroduce previously removed bacteria back into the water column. It was therefore assumed that bacteria removal rates for dry ED ponds were approximately half of those measured for wet ponds.

Table D.2: Range of Reported Removal Rates for Wet Ponds			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	60	80	90
Total Phosphorus	40	50	75
Soluble Phosphorus	40	65	75
Total Nitrogen	15	30	40
Organic Carbon	25	45	65
Total Zinc	40	65	70
Total Copper	45	60	75
Bacteria	50	70	95
Hydrocarbons	**60**	**80**	**90**
Chloride	0	0	0
Trash/Debris	**75**	**90**	**95**

Note: 46 wet ponds have been monitored over the past two decades so the removal rate range shown above should be reasonably accurate. **Hydrocarbon** and **trash/debris** removal rates should be considered provisional

Table D.3: Range of Reported Removal Rates for Stormwater Wetlands			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	45	70	85
Total Phosphorus	15	50	75
Soluble Phosphorus	5	25	55
Total Nitrogen	0	25	55
Organic Carbon	0	20	45
Total Zinc	30	40	70
Total Copper	20	50	65
Bacteria	**40**	**60**	**85**
Hydrocarbons	**50**	**75**	**90**
Chloride	0	0	0
Trash/Debris	**75**	**90**	**95**

Notes: 40 monitoring studies were available to define rates for total suspended solids, total phosphorus, soluble phosphorus, total nitrogen, organic carbon, total zinc and total copper for constructed wetlands. Only three studies measured **bacteria removal** by constructed wetlands. Research profiled in Strecker et al. (2004) indicated bacterial removal rates for constructed wetlands is generally positive, but typically lower than wet ponds. It was therefore assumed that bacteria removal rates would be at least 10% lower than in wet ponds.

Table D.4: Range of Reported Removal Rates for Bioretention Areas			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	**15**	**60**	**75**
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	5	50
Total Nitrogen	40	45	55
Organic Carbon	**40**	**55**	**70**
Total Zinc	40	80	95
Total Copper	40	80	95
Bacteria	**25**	**40**	**70**
Hydrocarbons	**80**	**90**	**95**
Chloride	0	0	0
Trash/Debris	**80**	**90**	**95**

Notes: Ten new bioretention monitoring studies have been released in the last few years that meet the quality control criteria to be included in the updated database so it is now possible to define removal rates for total phosphorus, soluble phosphorus, total nitrogen, total zinc and total copper. Surprisingly, there were only four studies to define the **total suspended solids removal rate**. Similar pollutant removal mechanisms operate in both bioretention and filtering practices (sedimentation, filtration). The median total suspended solids removal rate for filtering practices is similar to the high end rate for bioretention, which suggests that bioretention rates can be expected to go up as more performance data becomes available. No **bacteria removal rates** were available in the literature as of 2006. Initial research reported by Hunt and his colleagues in 2007 suggest that bacteria removal rates were high. Therefore, it was once again assumed that bioretention would function in the same manner as filtering practices and have similar removal rates. The **phosphorus removal rates** reported for bioretention are clearly bi-modal. Sites where the soil media had high phosphorus content tended to leach phosphorus and experience negative removal rates. Sites where soils with a low P-index volume consistently performed at the upper end of the phosphorus removal range. Again, as more performance data become available and soil media testing becomes standard, the range of rates for bioretention is expected to shift.

Table D.5: Range of Reported Removal Rates for Stormwater Filters			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	80	85	90
Total Phosphorus	40	60	65
Soluble Phosphorus	-10	5	65
Total Nitrogen	30	30	50
Organic Carbon	40	55	70
Total Zinc	70	90	90
Total Copper	35	40	70
Bacteria	25	40	70
Hydrocarbons	**80**	**85**	**95**
Chloride	**0**	**0**	**0**
Trash/Debris	**85**	**90**	**95**
Note: Nearly 20 studies have evaluated filtering practices, so reliable removal rates are reported for total suspended solids, total phosphorus, soluble phosphorus, total nitrogen, total zinc, total copper and bacteria. It should be noted that while total nitrogen removal is positive, most filters leak nitrate-nitrogen. Also, performance of vertical sand filters and the MCTT were excluded from the statistical analysis.			

Table D.6: Range of Reported Removal Rates for Infiltration Practices			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	**60**	**90**	**95**
Total Phosphorus	50	65	95
Soluble Phosphorus	**55**	**85**	**95**
Total Nitrogen	0	40	65
Organic Carbon	80	90	95
Total Zinc	65	65	85
Total Copper	**60**	**85**	**90**
Bacteria	**25**	**40**	**70**
Hydrocarbons	**60**	**90**	**95**
Chloride	**0**	**0**	**0**
Trash/Debris	**85**	**90**	**95**
Notes: Performance monitoring data for infiltration practices continue to be limited although the number of studies had doubled since 2000 (N=12). Total phosphorus, total nitrogen and total zinc all meet the minimum five-study test to be included for statistical analysis. Only three studies were available to characterize **total suspended solids, soluble phosphorus and total copper removal rates**. Recent research tends to confirm the range in removal rates (UNHSC, 2005). No data was found for **hydrocarbon, chloride and trash/debris** removal, so these were estimated using the general removal assumptions described earlier. **Bacteria removal rates** were also lacking, so it was once again assumed that they would be similar to those reported for filtering practices.			

Table D.7: Range of Reported Removal Rates for Swales			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	70	80	90
Total Phosphorus	-15	25	45
Soluble Phosphorus	-95	-40	25
Total Nitrogen	40	55	75
Organic Carbon	55	70	85
Total Zinc	60	70	80
Total Copper	45	65	80
Bacteria	**- 65**	**-25**	**25**
Hydrocarbons	**70**	**80**	**90**
Chloride	0	0	0
Trash/Debris	**0**	**0**	**50**

Notes: 17 studies were available from the database to establish removal rates for total suspended solids, total phosphorus, soluble phosphorus, total nitrogen, total zinc and total copper. Only four studies were available for bacteria removal and all were negative. However, a positive 25% rate was established for the high end, since pollutant removal mechanisms in dry swales should have some capability to remove bacteria in the soil. Several studies monitored chloride and found only negative removal. No removal data was available for trash/debris, although it was presumed to be low due to washout of trash during high flows. A 50% removal rate was established for the high end for swale designs that contain treatment cells with actual trapping capability.

Appendix 6 – Center for Watershed Protection's 2007 *Urban Stormwater Retrofit Practices*, Appendix E: Derivation of Unit Costs for Stormwater Retrofits and New Stormwater Treatment Construction

Appendix E: Derivation of Unit Costs for Stormwater Retrofits and New Stormwater Treatment Construction

I. Basic Approach, Findings and Caveats

A. Basic Cost Approach

The cost analysis involved a review of existing cost studies for new stormwater treatment options including studies by Wossink and Hunt (2003), Brown and Schueler (1997), Hathaway and Hunt (2006), WDNR (2003), LGPC (2003), Chicago DEP (2003), Liptan and Strecker (2003) and WSSI (2006). In addition, Hoyt (2007) performed an analysis of actual retrofit construction costs for nearly 100 projects around the country with the following sample size: new storage retrofits (N= 16), pond retrofits (N=31), on-site bioretention retrofits (N =18) and other retrofits (N = 29).

The basic approach was as follows:

- All construction costs were indexed and updated to 2006 dollars using the Engineering News Record Construction Cost Index (RS Means, 2006)
- All studies that utilized cost equations were solved for common retrofit boundary conditions to create a cost range (e.g., drainage area and impervious cover). For example, the range in pond costs was bounded at the high end (10 acres CDA, 15% IC) and the low end (250 acres CDA and 65% IC)
- Retrofit costs were expressed on a common basis ($/cubic foot treated or $/impervious acre treated)
- Total costs were calculated as the base construction cost multiplied by the design/engineering (D&E) rate. Both factors differed between new BMP and retrofit construction
- While a median cost is given for each new stormwater practice or retrofit type, cots are best expressed as a range. In most cases, the range was defined as the 25 to 75% quartiles of the known costs.
- When multiple cost estimates differed for the same retrofit practice, original studies were analyzed for cost-specific factors to explain the difference in terms of design or labor factors that might develop more predictive cost categories.
- Some engineering judgment was needed to classify costs such as the differential costs between new stormwater and retrofit construction.

B. Findings

- Retrofit costs are extremely variable depending on site conditions and retrofit design complexity. In many cases, construction costs were an order of magnitude different for the same volume of stormwater treated (Table E.1).
- Retrofit base construction costs generally exceeded the cost of new stormwater practices by a factor of 1.5 to 6.
- Construction costs for storage retrofits are generally lower than on-site retrofits based on the cost per impervious acre treated. The most influential retrofit cost

factor is the total acreage of impervious cover treated by a retrofit. Unit costs decline as acreage treated increases. By contrast, smaller on-site retrofits that treat less than a ½ acre of impervious cover tend to be two orders of magnitude more expensive per treated area than storage retrofit practices.

- Design and engineering (D&E) costs for storage retrofits exceed those for new stormwater practices when their much higher base retrofit construction costs are factored in.
- The D&E estimate for pond construction derived by Brown and Schueler (1997) of 32% was used to define costs for project management, design, permitting, landscaping and erosion and sediment control
- A 32% D&E rate also applies to on-site retrofits, based on Hoyt's 2007 review of the D&E costs for 17 projects.
- The components of D&E costs differ between storage retrofits (where permitting, and engineering studies dominate) than on-site retrofits (where design and project management dominates).
- A 40% D&E rate should be used for any retrofit requiring major environmental permits.
- The D&E rate differs based on retrofit location. For example, a 5% value was assigned for little retrofits, rain barrels and small rain gardens

Table E.1: Retrofit Construction Costs
2006 $ to Treat an Impervious Acre

Retrofit Type	Low End [1]	Median	High End
Pond Retrofit	$ 3,600	$ 11,100	$ 37,100
New Storage Retrofit	$ 9,000	$ 19,400	$ 32,200
Urban On-site Retrofit [2]	$ 58,000	$ 88,000	$ 150,000

[1] Low end is the 25% quartile value, high end is the 75th quartile value
[2] Mean contributing drainage area to practice = 0.58 acres

Table E.2: Base Construction Costs for New Stormwater Practices BMPs
2006 $ per impervious acre treated

Stormwater Practice	Low End	Median	High End	Source:
Constructed Wetlands [1]	$ 2,000	$ 2,900	$ 9,600	Cost Equation
Extended Detention [1]	2,200	3,800	7,500	Cost Equation
Wet Ponds [1]	3,100	8,350	28,750	Cost Equation
Water Quality Swales [2]	10,900	18,150	36,300	Derived
Bioretention	19,900	25,400	41,750	Cost Equation
Infiltration [3]	19,900	25,400	41,750	Derived
Residential Rooftop	10,900	27,200	49,000	Derived
Filtering Practices	18,150	58,100	79.900	Cost Equation
Non-Residential Roof	21,800	90,750	1,100,000	Derived

[1] based on typical range of CDA and IC noted in the basic approach section
[2] Derived from a cost per square foot
[3] Assumed to be comparable to bioretention costs
Please check documentation notes for all practices later in Part II of this Appendix

Base retrofit costs can be compared to the costs for constructing new stormwater practices shown in Table E.2. The cost ranges shown for new stormwater practices should not be used to estimate retrofit costs unless the designer is confident that all the site conditions outlined in Table E.3 can be met. Few proposed retrofit sites will meet these conditions.

Table E.4 compares the range in unit treatment costs for a large number of retrofit techniques while Chapter 2 offers more detailed cost data for each retrofit location in a subwatershed.

Table E.3: Guidance on when new STO cost equations can be used
• Abundant surface land is present on the site to provide flexibility in retrofit layout and design • Site has adequate head and has no major utilities to work around • Site topography is such that a neutral earthwork balance can be achieved (i.e., no off-site hauling) • No flow splitters, riser modifications or other special plumbing is needed to make the site work • No significant environmental permits are required • No major landscaping or planting plan is needed in the design

Table E.4 Range of Retrofit Costs (2006 $ per cubic foot of runoff treated)

Retrofit Technique	Median Cost	Range
Pond Retrofits	$ 3.00	$ 1.00 to 10.00
Rain Gardens	$ 4.00	$ 3.00 to 5.00
New Storage Retrofits	$ 5.00	$ 2.50 to 9.00
Larger Bioretention Retrofits	$ 10.50	$ 7.50 to 17.25
Water Quality Swale Retrofit	$ 12.50	$ 7.00 to 22.00
Cisterns	$ 15.00	$ 6.00 to 25.00
French Drain/Dry Well	$ 12.00	$ 10.50 to 13.50
Infiltration Retrofits	$ 15.00	$ 10.00 to 23.00
Rain Barrels	$ 25.00	$ 12.50 to 40.00
Structural Sand Filter	$ 20.00	$ 16.00 to 22.00
Impervious Cover Conversion	$ 20.00	$ 18.50 to 21.50
Stormwater Planter	$ 27.00	$ 18.00 to 36.00
Small Bioretention Retrofits	$ 30.00	$ 25.00 to 40.00
Underground Sand Filter	$ 65.00	$ 28.00 to 75.00
Stormwater Tree Pits	$ 70.00	$ 58.00 to 83.00
Permeable Pavers	$ 120.00	$ 96.00 to 144.00
Extensive Green Rooftops	$ 225.00	$ 144.00 to 300.00
Intensive Green Rooftops	$ 360.00	$ 300.00 to 420.00
Note: Costs shown are base construction costs and do not include additional D&E costs, which can range from 5 to 40%		

C. Caveats

The cost analysis described herein is subject to a number of important caveats that should be fully understood before using it to estimate retrofit project costs.

- Construction costs vary regionally based on labor rates, construction materials and design standards. The new construction cost data were largely drawn from North Carolina and Maryland studies, while retrofit cost data were derived from a larger national cross-section of projects (VA, NY, DE, CA, TX, OR, MD, OR, VA).

- Most on-site retrofits included in the national cost database were experimental designs or demonstration projects that had high initial construction costs. It is expected that unit retrofit costs will stay the same or even decline in future years as designers gain more experience and utilize more cost-effective and standardized construction techniques for these practices.

- All construction costs shown here exclude land acquisition costs. If land must be acquired, retrofit costs increase sharply, and some costly retrofit options, such as underground treatment, become more cost-effective.

- Construction costs do not include the costs needed to find the retrofit site (i.e., costs to perform a retrofit inventory, develop a concept design, assess project feasibility or rank priority projects in a subwatershed plan).

- Limited data were available to derive costs for several stormwater treatment options including infiltration and water quality swales, and some on-site retrofit techniques (e.g., expanded tree pits). These estimates should be viewed with caution until more actual retrofit cost data is generated.

- The base construction cost does not include costs for retrofit design and engineering (D&E) that is estimated by multiplying base construction cost of storage retrofits by a fixed percentage ranging from 5 to 40%. For on-site retrofits, the D&E factor ranges from 5 to 32%.

- Retrofit costs can be extremely variable, and actual costs for individual retrofit projects can significantly exceed the range shown, depending on site conditions. Designers should carefully evaluate the retrofit construction inflators/deflators shown in Chapter 2 and adjust their cost estimates accordingly.

- The construction cost for several on-site retrofits such as permeable pavers and green rooftops do not reflect the incremental cost difference of the surface they substitute or replace (e.g., regular asphalt vs. permeable pavers; conventional rooftop vs. green rooftop). If the surface needs replacing, actual retrofit costs should be expressed as the incremental cost difference from the conventional surface and the new retrofit.

- Reported costs for several on-site retrofits such as bioretention, rain gardens, and rain barrels vary greatly depending on whether it is assumed they will be designed and installed by volunteers or by paid contractors. Even when on-site retrofits are installed by volunteers, localities may still need to incur a retrofit delivery cost to make them happen.

- The water quality sizing assumption for this retrofit cost analysis was treatment of one inch of runoff per impervious acre acre (or 3630 cubic feet of storage per impervious acre). If local water quality sizing target criteria depart from this assumption, the cost data should be adjusted accordingly.

II. Documentation of Unit Cost Data

This section outlines the assumptions and methods used to derive unit costs for new stormwater practices and retrofit practices.

A. ED Ponds

New Construction: The Brown and Schueler (1997) ED pond cost equation was updated to 2006 dollars using the ENR Construction Cost Index, which yielded the following equation:

$$CC = (11.54)(V_s^{0.780})$$

Where
V_s = storage volume in cubic feet

The equation was then solved for a common set of retrofit boundary conditions to create a range of expected construction costs:

Low end: 250 acre contributing drainage area (CDA) and 65% impervious cover (IC)
Average: 50 acre CDA and 35% IC
High end: 10 acre CDA and 15% IC

The base construction costs for each boundary condition were then converted into costs per impervious acre treated.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that used ED in combination with other stormwater practices to achieve full retrofit treatment. When these results are compared to the costs for new ED pond construction, it is evident that retrofits are about five times more expensive (median: $19,440 per impervious acre treated vs. $3,800). The median retrofit cost for new storage retrofits in Table E.1 should be used if the proposed ED retrofit is combined with wetland and/or wet pond treatment. The lower end cost of $ 9,000 is more appropriate for standalone ED retrofits. The new ED pond cost equation can be used if the retrofit satisfies the construction conditions outlined in Table E.3.

B. Wet Pond

New Construction: The same basic methods were used to update the three new wet pond construction costs from Brown and Schueler (1997) and Wossink and Hunt (2003). The updated 2006 equations are as follows:

Wet extended detention ponds
$$CC = (12.02)(V_s^{0.750})$$
Wet ponds
$$CC = (277.89)(V_s^{0.553})$$
Wet ponds:
$$CC = (17,333)(A^{0.672})$$

where A = contributing drainage area (acres) and only applies to CDA from 1 to 67 acres

The three equations were solved for the same retrofit boundary conditions established for ED ponds to define a low, middle and high-end range for expected construction costs. The results from all three equations were averaged, although the low end of the W&H equation was omitted because it was outside of the data range of its sample ponds. Unit construction costs for each boundary condition were then converted into cost per impervious acre treated.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that relied on wet ponds for water quality treatment. When these costs are compared to the costs for new wet pond construction, it is evident that retrofits are about 2.3 times more expensive than new stormwater wetland construction (median: $19,440 vs. $8,350). This difference is reasonable given the more complicated construction conditions expected at wet pond retrofit sites. The median retrofit cost shown in Table E.1 is recommended for planning purposes, subject to the construction cost inflators/deflators outlined in Chapter 2. In rare cases, the new wet pond cost equations can be used if the retrofit site satisfies the new development construction conditions outlined in Table E.3.

C. Constructed Wetlands

New Construction: The same basic methods were used to update the two wetland construction costs derived by Brown and Schueler (1997) and Wossink and Hunt (2003) into 2006 dollars. The adjusted equations are as follows:

All ponds and wetlands

$$CC = (29.43)(V_s^{0.701})$$

Stormwater wetlands

$$CC = (4{,}800)(A^{0.484})$$

Note: Equation applies to 4 – 200 acre CDA

The equations were solved for the previously stated retrofit boundary conditions to create a range of expected construction costs, although the cost estimates generated between the two equations were not always in close agreement. For example, the low-end wetland cost estimate predicted by the Wossink and Hunt equation was omitted from the analysis because it is outside of the range of their wetland sample population. Some engineering judgment was needed to reconcile the low-end, middle and high-end unit costs for constructed wetlands.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that combined constructed wetlands with ED and/or wet ponds to achieve treatment. When these results are compared to the costs for new constructed wetland construction, retrofits appear to be nearly 7 times more expensive (median: $19,440 vs. $2,900). At first glance, this discrepancy is difficult to explain, but involves the inherent difference between new and retrofit construction of stormwater wetlands. The cost for new constructed wetlands is comparatively low since their shallow design requires much less excavation (which is normally the greatest component of base construction cost). Designers essentially rely on a greater site footprint to save excavation costs, which is seldom available in a retrofitting situation. Very few retrofits in the Hoyt (2007) database were solely constructed wetlands; most devoted considerable storage to extended detention and wet pond treatment in order to squeeze the wetland into a tight retrofit site.

Consequently, the median new storage retrofit unit cost in Table E.1 is reasonable to use if constructed wetlands are designed with ED or wet ponds cells. Designers may wish to adjust this cost higher or lower depending of the site-specific construction cost inflators/deflators outlined in Chapter 2. If it is an ideal site, and corresponds to the new development construction conditions outlined in Table E.3, the most appropriate new constructed wetland cost equation can be used as an alternate.

D. Bioretention

New Construction: Several equations were updated to estimate new bioretention costs on projects greater than one acre in contributing drainage area (Brown and Schueler, 1997 and Wossink and Hunt 2003). Adjusted to 2006 dollars, the two equations are:

$CC = (8.02)(WQ_V^{0.990})$
$CC = (12{,}664)(A^{1.088})$ *(clay soils)*

These equations apply to more engineered bioretention areas and typically include underdrains, soil media and some type of pretreatment cell. The Wossink and Hunt equation for bioretention in sandy soils (where underdrains are not needed and less soil amendment is required) were not used, since this is not a common condition for retrofits on disturbed urban soils. The equations were solved for several hypothetical retrofit situations to establish expected boundary conditions as follows:

1.0 acre CDA and 100% IC
1.5 acre CDA and 65% IC
3.0 acre CDA and 35% IC

This approach helped define a low-end, middle and high-end unit costs for bioretention. Some engineering judgment was needed since the two equations were not always in agreement. For example, the low-end prediction from the Wossink and Hunt equation appeared unrealistically low and the middle value of ($5.50/cubic foot) was used to tie down the low end unit cost for new bioretention construction instead. The resulting cost estimates were then compared against the unit costs for rain gardens reported by Hathaway and Hunt (2006) and were found to be in general agreement.

Retrofit Construction: The cost of bioretention retrofits varies greatly depending on the contributing drainage area, design objective, installer and site conditions at the proposed retrofit site. Therefore, a four-tiered approach was used to define retrofit costs:

1. *Small highly urban retrofits*: The Hoyt (2007) database contained numerous bioretention retrofits built on highly urban uses with less than a half acre of CDA. The median cost for these bioretention retrofits was 3.5 times greater than the cost for a new bioretention area ($88,000 vs. $25,500 per impervious acre treated). The higher cost is due to need for demolition, extensive landscaping, full media replacement, underdrains and new connections to existing storm drain system. In addition, these retrofits are all professionally installed. Consequently, an average cost range of $25 to $40 per cubic foot treated is recommended for bioretention retrofits with less than 0.5 acre CDA. The higher end of the range applies when bioretention retrofits are designed as a landscape feature (i.e., special stone, intensive plant materials and special grading/berms).

2. *Rain gardens*: Numerous researchers have reported a much lower unit cost ($3 to $5 per cubic foot) to construct rain gardens (Hathaway and Hunt, 2006, WDNR (2003) and WSSI (2006). The term "rain gardens" is used here to define shallow bioretention areas in relatively permeable soils that lack underdrains and are installed with volunteer labor. This situation may occur

for homeowner installation of rain gardens and some demonstration retrofits.

3. *Typical bioretention retrofits*: Most bioretention retrofits fall between these two extremes, but are still likely to exceed the costs for new bioretention areas. Bioretention retrofits typically require more pretreatment, re-grading, new inlets and intensive landscaping than their new development counterparts. Not much data, however, were available to define this cost difference. Based on engineering judgment, a multiplier of 1.5 was applied to the new bioretention unit cost data to reflect the expected costs for typical bioretention retrofits ($10.50 per cubic foot treated, range of $7.50 to $17.75). Designers should adjust the project estimate to reflect the site-specific construction cost inflators/deflators described in Chapter 3.

4. *Ideal bioretention retrofits*. Some proposed sites are a natural for bioretention retrofit (e.g., abundant treatment area located in a depression, use of simple curb cuts to direct runoff into the retrofit, sandy soils, a simple planting plan etc.). Retrofit sites that satisfy the new development site conditions in Table E.3 may use unit costs for new bioretention construction (median $7.00 range of $5.50 to 10.50 per cubic foot treated)

E. Filtering Practices

New Construction: The costs for new stormwater filters depend on the complexity of their design, so a tiered cost estimation approach was followed. Sand filters were classified into three categories, as follows:

1. Surface sand filter (no concrete poured and no major structural elements)
2. Structural sand filter (perimeter or surface filter w/ two cells with major concrete/structural elements or special media)
3. Underground sand filter (deep excavation, concrete vault construction and special treatment media)

The Brown and Schueler (1997) cost equation was updated to 2006 dollars to define costs for surface sand filters, whereas the Wossink and Hunt (2003) equation was relied on to define costs for structural sand filters:

$CC = (59{,}678)(A^{0.882})$
Note: Applies to CDA of 0.5 to 9 acres

The cost equations were solved the equation for typical retrofit boundary conditions, as follows:

1.0 acre CDA and 100% IC
1.5 acre CDA and 65% IC
3.0 acre CDA and 35% IC

Based on these boundary conditions, expected low-end, middle and high-end values were determined for surface and structural sand filters. Some engineering judgment was used to adjust the high end predictions of the Wossink and Hunt equation downward, based on cross-checking with earlier cost estimates reported by Schueler (2000a).

Two sources were used to derive unit construction costs for underground sand filters (Schueler, 2000a) and Hoyt's 2007 review of nine underground and multi-chamber treatment train retrofit projects. The costs were quite variable, but a projected cost range of $28 to $75 covered most of the projects.

Retrofit Construction – Given limited cost data and the similarity between new and retrofit filter costs, the three tier approach for estimating filtering practice costs was not adjusted to account for retrofitting. It was also reasoned was that most sand filters for new development are built at tight and constrained sites that are comparable to most retrofit situations.

F. Infiltration Practices

New Construction - No new construction cost data was discovered in the literature to estimate the unit costs to construct new infiltration practices. Given the inherent similarity in the construction process between bioretention and infiltration, it was therefore assumed that infiltration construction costs would be equivalent for new bioretention areas (see Table E.2).

Retrofit Construction – Very little infiltration retrofit cost data has been reported, presumably because of poor urban soil conditions have limited their use. It was assumed that infiltration retrofit costs would be twice that of new bioretention areas to account for expanded soil testing, pretreatment cells, erosion and sediment control and landscaping.

H. Water Quality Swales

New Construction – Several assumptions and methods were needed to derive unit construction costs for new water quality swales, which are frequently reported on a linear foot (Claytor, 2003) or a square foot basis (Hathaway and Hunt (2006). Most estimates are for grass swales that use checkdams to get surface storage. No data were available for dry swales which are similar in construction to bioretention areas (e.g., underdrains and full media replacement). It was assumed that this class of water quality swales would be equivalent to the high end of new bioretention areas reported in Table E.2

The unit costs for water quality swales reported by Claytor (2003) were updated to 2006 dollars, and were converted to a per cubic foot basis using the following common retrofit channel conditions:

- 4 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($8.20/cubic foot)
- 8 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($4.75/cubic foot)
- 12 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($3.50/cubic foot)

Consequently, the low end for new water quality swale costs was established using the Claytor approach, and the high end using "running" bioretention.

Retrofit Construction- Swale retrofit costs were assumed to be twice that of new water quality swale construction due to the need for greater re-grading, creation of multiple cells, vegetation establishment, soil amendments, and work within tight easements.

I. Other On-Site Retrofit Techniques

The last group of retrofit cost data is the data for individual on-site practices. Cost data for these practices were derived from recent cost studies. Cost data were generally converted to a per cubic foot basis using unit conversions and assumptions about typical treatment areas. The particular methods used to derive the cost data for each of the individual on-site practices are summarized below.

1. Stormwater Planters

Cost data from Hoyt (2007) was used to develop the unit costs for stormwater planters.

- Range: $83,500 to $104,500 per impervious acre treated

A unit conversion factor of 3630 CF was used to convert the impervious acre treated data to a per cubic foot basis:

- Range: $23.00/CF to $29.00/CF

The median cost was set at $26.00/CF and a cost range was established assuming that the low end and high end costs were 30% lower and higher than the median cost. The resulting range was $18.00/CF to $34.00/CF.

2. Cisterns

Cost data from Hoyt (2007) and Hathaway and Hunt (2006) were used to develop the unit costs for cisterns.

- Range: $20,000/IC to $80,000/IC
- Range: $1.00/gal to $3.00/gal

Unit conversions were used to convert the cost data to a per cubic foot basis:

- Range: $5.50/CF to $22.00/CF
- Range: $7.50/CF to $22.00/CF

Based on the results, a median cost was established at $15.00/CF (range:$6.00/CF to $22.00/CF).

3. Green Roofs

Updated cost data from Hoyt (2007), Chicago (2003), Portland BES (2006a) and WSSI (2006) were used to develop the unit costs for green roofs.

Extensive Green Roofs

- Range: $405,500 /IC to $770,500/IC (Hoyt, 2007)
- Range: $9.50/SF to $14.00/SF (Chicago, 2003)
- Range: $10.00/SF to $15.00/SF (Portland BES, 2006a)

Intensive Green Roofs

- Range: $18.00/SF to $30.00/SF (Chicago, 2003)
- $32.00/SF (WSSI, 2006)

Unit conversions were used to convert the cost data to a per cubic foot basis.

Extensive Green Roofs

- Range: $110/CF to $215/CF (Hoyt, 2007)
- Range: $115/CF to $170/CF (Chicago, 2003)
- Range: $120/CF to $180/CF (Portland BES, 2006a)

Intensive Green Roofs

- Range: $215/CF to $360/CF (Chicago, 2003)
- $385/CF (WSSI, 2006)

Based on the results, the median and ranges for extensive and intensive green roofs were established.

Extensive Green Roofs

- Range: $110/CF to $225/CF
- Median: $170/CF

Intensive Green Roofs

- Range: $225/CF to $400/CF
- Median: $310/CF

4. Permeable Pavers

Hathaway and Hunt (2006) re ported a $10/SF unit cost for permeable pavers.

Unit conversions, based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF), were used to convert the cost data to a per cubic foot basis.

- $120/CF

The range of costs was established by assuming that the low end and high end costs are 30% lower and higher, respectively, than the median cost. The resulting cost range was $80/CF to $160/CF.

5. Rain Barrels

Cost data from Hathaway and Hunt (2006) and Portland BES (2006b) were used to develop the unit costs for rain barrels.

- Range: $50 to $300 per 55 gallon rain barrel (Portland BES, 2006b)
- $320 per 55 gallon rain barrel (Hathaway & Hunt, 2006)

Unit conversions were used to convert the cost data to a per cubic foot basis.

- Range: $7.50/CF to $41.00/CF (Portland BES, 2006b)
- $43.50/CF (Hathaway & Hunt, 2006)

Based on the results, the median and range were set at $25.00/CF and $7.50/CF to $40.00/CF, respectively.

6. Rain Gardens

Cost data from Hathaway and Hunt (2006) and WDNR (2003) were used to develop the unit costs for rain gardens.

- Range: $3.00/SF to $5.00/SF (Hathaway & Hunt, 2006)
- Range (homeowner installation): $3.00/SF to $5.00/SF (WDNR, 2003)
- Range (professional installation): $12.00/SF to $15.00/SF (WDNR, 2003)

The costs were converted to a cubic foot basis assuming the runoff from one inch of rainfall from one impervious acre (3,630 CF) and assuming a 12 inch ponding depth within the rain gardens.

Based on the results, three categories of rain garden installation were defined. These included volunteer installation, professional installation with standard landscaping and professional installation with deluxe landscaping:

Volunteer Installation
It was assumed that the cost data presented by Hathaway and Hunt (2006) represented the construction cost for rain gardens installed by volunteers. Therefore, the median and range were set at $4.00/CF and $3.00/CF to $5.00/CF, respectively, for rain gardens installed by volunteers.

Professional Installation with Standard Landscaping
We assumed that the construction cost for professionally installed rain gardens with standard landscaping was somewhere between the other two types of installations (e.g. volunteer installation and professional

installation with deluxe landscaping). The median and range were set at $7.50/CF and $5.00/CF to $10.00/CF, respectively.

This cost data matches well with the cost data presented for the "ideal bioretention retrofit" scenario. The two applications are very similar (e.g. professional installation, practice located in depressional area, simple conveyance to practice, sandy soils with no need for underdrain, simple planting plan), so the construction cost of the two practices should be similar.

Professional Installation with Deluxe Landscaping

It was assumed that the cost data presented by WDNR (2003) represented the construction cost for professionally installed rain gardens with deluxe landscaping (e.g. decorative stone, intensive landscaping). Therefore, the median and range were set at $12.50/CF and $10.00/CF to $15.00/CF, respectively.

7. French Drains/Dry Wells

Cost data from LGPC (2003) was used to develop the unit costs for french drains and dry wells.

- Range: $15/LF to $17/LF

In order to convert the cost data to a per cubic foot basis, the length of a french drain needed to treat one inch of runoff from one impervious acre was calculated. It was assumed that the french drain would be 2 feet deep and 2 feet wide (e.g. the dimensions of a typical french drain) and that the gravel used to fill the french drain would have a void ratio of 0.35. Based on these assumptions, 2,595 linear feet of french drain would be needed to treat 1 acre of impervious cover (e.g. [43,560 SF * 1 IN] ÷ [12 IN/FT * 2 FT * 0.35] ÷ 2 FT = 2,595 FT).

- Range: $10.50/CF to $12.50/CF

Based on the results, the range was set at $10.50/CF to $12.50/CF. The average unit cost (e.g. $11.50/CF) was set as the median.

8. Impervious Cover Conversion

Cost data from RS Means (2006) were used to develop the unit costs for impervious cover conversion.

- Asphalt Removal: $40,000/AC
- Concrete Removal: $55,000/AC
- Site Restoration: $26,150/AC

Site restoration includes soil preparation, fine grading, seeding and erosion control (Table 1).

A unit conversion, based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF), was used to convert the cost data to a per cubic foot basis.

- Asphalt Removal: $11.00/CF
- Concrete Removal: $15.00/CF
- Site Restoration: $7.00/CF

The range was established by assuming that the costs for asphalt and concrete removal represent the low end and high end costs, respectively, for impervious cover removal. The range was therefore set at $18.00/CF to $22.00/CF. The average unit cost (e.g. $20.00/CF) was set as the median cost.

Table 1: Site Restoration for Impervious Cover Conversion		
Description	Unit Cost	Unit
Soil preparation (till topsoil)	$0.05	SF
Fine grading	$0.25	SF
Seeding (prairie/meadow mix)	$0.05	SF
Erosion control blanket	$0.25	SF
Total cost	$0.60	SF
Source: RS Means, 2006		

9. Filter Strips

Cost data from RS Means (2006) were used to develop the unit costs for filter strips.

- Site Restoration: $0.70/SF
- Level Spreader: $4.00/LF

Site restoration includes brush clearing and removal, soil preparation, fine grading, seeding and erosion control (Table 2).

A unit conversion based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF) was used to convert the square foot filter strip cost data to a per cubic foot basis. To convert the unit cost for the level spreader, it was assumed that the overland flow path in the filter strip's contributing drainage area would be 75 feet long (the use of a longer overland flow path would not ensure that sheet flow is provided to the filter strip). Based on this assumption, 580 linear feet of filter strip and level spreader would be needed to treat 1 acre of impervious surface (e.g. 43,560 SF ÷ 75 FT = 580 FT).

- Level Spreader: $2,320/IC
- Level Spreader: $0.60/CF

To convert the unit cost for site restoration, it was assumed that the minimum filter strip width would be 25 feet and the maximum filter strip width would be 75 feet. Based on these assumptions, a minimum of 14,500 square feet and a maximum of 43,500 square feet would be need to treat 1 acre of impervious cover (e.g. 580 FT * 25 FT = 14,500 SF and 580 FT * 75 FT = 43,500 SF)

- Site Restoration: $10,000/IC to $30,500/IC
- Site Restoration: $3.00/CF to $8.50/CF

Based on the results, the range was set at $3.50/CF to $8.50/CF. The average unit cost ($6.00/CF) was set as the median.

10. Soil Compost Amendment

Cost data provided by Schueler (2000b), updated to 2006 dollars, was used to develop the unit costs for soil compost amendments.

- Range: $0.27/SF to $0.98/SF

Unit conversions were used to convert the cost data to a per cubic foot basis.

- Range: $3.20/CF to $11.80/SF

Based on the results, the median and range were set at $7.50/CF and $3.20/CF to $11.80/CF, respectively.

11. Street Bioretention Areas

The cost data compiled by Hoyt (2007) includes data from a number of small bioretention retrofits built in highly urbanized areas with less than 0.5 acres of contributing drainage area. The construction of these retrofits requires professional installation and demolition, soil replacement, underdrains, connections to the existing storm drain system and extensive landscaping.

The construction of street bioretention areas requires equally careful construction. Therefore, the construction cost of street bioretention areas was assumed to be the same as that of small, highly urban bioretention retrofits. The median and range were set at $30.00/CF and $25.00/CF to $40.00/CF, respectively. The higher end of the range should be used when the bioretention area is designed as a landscape feature (e.g., decorative stone, intensive landscaping)

Table E.2: Site Restoration for Filter Strips		
Description	**Unit Cost**	**Unit**
Site preparation (brush clearing and removal)	$0.10	SF
Soil preparation (till topsoil)	$0.05	SF
Fine grading	$0.25	SF
Seeding (prairie/meadow mix)	$0.05	SF
Erosion control blanket	$0.25	SF
Total cost	$0.70	SF
Level spreader (based on 1 CF stone/LF)	$4.00	LF
Source: RS Means, 2006		

Appendix 7 – Stormwater Management Pond Evaluation Data Dictionary

Pond Points (General Information)

These points will be collected for general location and to add the general overall condition of the pond. The attributes collected for this feature type are the following:

Inspection Number: The unique ID of the pond (user assigned).

Date: The date the inspection was done on the pond. This will be auto filled with the current date of on the data logger.

Weather: The current weather conditions, this will be a drop down box with the following options <Wet or Dry>.

Pond Type: The type of pond the inspection is being performed on. This will be drop down box with the following options <Wet, Dry, Other>.

Standing Water: This will hold information on the ponds contents, it will be a drop down box with the following options <Yes or No>.

Siltation: The amount of siltation within the pond, this will be a drop down box with the following options <None, Light, Moderate Heavy>.

Unwanted Vegetation: Indicates if there is unwanted vegetation within the pond. This will be a drop down box with the following options <None, Minimal, Sparse, Thick>.

Emergency Spillway: Signals if there is an emergency spillway attached to the pond. This will be a drop down box with the following options <Yes or No>.

Spillway Condition: The condition of the spillway attached to the pond. This will be a drop down box with the following options <Good, Fair, Poor>.

Spillway Width: The width of the spillway attached to the pond.

Spillway Cover: The covering of the spillway, the material used. This will be a drop down box with the following options<Concrete, Gabion, Reinforced Earth, Rip Rap, Vegetated, other>.

Outlet Structure OS Points

The Outlet Structure OS Points will be a very large form because of the amount of data collected around this particular feature. It might be a little cumbersome at first but once the field people get into a "system" this should be able to fill the form out without any problems. Below is the information that will be collected for this particular feature type:

OS Condition: The condition of the outlet structure in general. This will be a drop down box with the following options <good, fair, poor>.

OS Height (decimal feet): How tall the OS structure is from ground to top.

OS Invert (decimal feet): Depth of the OS structure from top to bottom (inside).

OS Diameter/Width (decimal feet): Outlet Structure width if is rectangle or diameter if it is round.

OS Length (decimal feet): Outlet Structure length if is rectangle (if round field will be left blank).

OS Material: The material of the Outlet Structure, this will be a drop down box with the following items for options; <CMP, Concrete, HDPE, PVC, TCP, Other>.

Number of Orifices: The total number of observed orifices on the Outlet Structure. This will be a drop down box with the following range of values <1-10>.

Orifice 1 Diameter/Width (decimal feet): The diameter for a round orifice or width if rectangle.

Orifice 1 Height (decimal feet): The height for a rectangle orifice if round the field will be left blank.

Orifice 1 Height from Shot (decimal feet): The vertical distance from the GPS ground shot to the orifice invert.

Orifice 1 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 2 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 2 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 2 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 2 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 3 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 3 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 3 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 3 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 4 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 4 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 4 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 4 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 5 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 5 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 5 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 5 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 6 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 6 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 6 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 6 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 7 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 7 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 7 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 7 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 8 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 8 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 8 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 8 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 9 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 9 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 9 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 9 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Orifice 10 Diameter/Width: The diameter for a round orifice or width if rectangle.

Orifice 10 Height: The height for a rectangle orifice if round the field will be left blank.

Orifice 10 Height from Shot: The vertical distance from the GPS ground shot to the orifice invert.

Orifice 10 Access: This will store if the orifice is clear or blocked by sediment or debris. This will be a drop down box with the options to select <Clear or Block>.

Weir Width 1 (decimal feet): The width of the first weir measured.

Weir 1 Height from Shot (decimal feet): The vertical distance from the GPS ground shot to the weir invert.

Weir Width 2: The width of the second weir measured.

Weir 2 Height from Shot: The vertical distance from the GPS ground shot to the weir invert.

Weir Width 3: The width of the third weir measured.

Weir 3 Height from Shot: The vertical distance from the GPS ground shot to the weir invert.

Weir Width 4: The width of the fourth weir measured.

Weir 4 Height from Shot: The vertical distance from the GPS ground shot to the weir invert.

Outfall Points

The outfall point's form will be small compared to the previous form for outlet structure. The following is the data collected for the outfall feature type:

Condition: The condition of the outfall pipe where the shot is taken with the GPS unit. This will be a drop down box with the following option to choose from <Good, Fair, Poor>.

Pipe Material: The material of the pipe where the shot of the outfall is taken. This will be a drop down box with the following options to choose from <CMP, HDPE, PVC, RCP, Other>.

Interior Type: Is the pipe interior smooth or corrugated? <smooth, corrugated>.

Pipe Diameter/Width (decimal feet): The interior diameter of the pipe if is round or the width of the pipe if it is rectangular.

Pipe Height (decimal feet): The interior height of the pipe if it is rectangular, it remain empty if the pipe is round.

Discharge Location: The entity of the discharge location. This will be a drop down box with the following options <Stream, Wetland, Storm Sewer, Other>.

Spot Elevations Points

The Spot Elevation Points will be repetitive shots at locations where you would like to know elevations. I removed this function from the spillway feature you marked in your notes. The person taking the shot wouldn't want to see all the information every time they take a shot. So this is a simple point they can take with few attributes.

Location: This will record the spot on the slope; it will be a drop down box with the following options <Spillway Invert Toe of Slope, Spillway Center Line, Spillway Top of Slope, Top of Slope, Middle of Slope, Bottom of Slope>.