PHASE II STORM WATER MANAGEMENT PLAN
FOR THE
LAKE ERIE WATERSHED
INTERIM REPORT
FOR THE PERIOD OCTOBER 1, 1994 THROUGH SEPTEMBER 30, 1995

DER GRANT/CONTRACT NO. - CZ1:94.01PE
GRANT TASK NO. - CZ1:94.05PE
ME NO. - 94465

A REPORT OF THE PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES TO THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION PURSUANT TO NOAA AWARD NO. - NA470Z0248

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PART 1: PROJECT STATUS REPORT

CHESTER ENVIRONMENTAL

Ref. No. 4026-02

September 27, 1995

SEP 27 1995

Mr. John Mong
Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

Dear Mr. Mong:

Re: Lake Erie Area Watershed Stormwater Management Plan
30-Month Project Status Report

I am pleased to provide the following report on the status of the Lake Erie Area Watershed Stormwater Management Plan at this the 30-month point in the project.

GENERAL

On March 1, 1993, Erie County authorized Chester Environmental to complete a Phase II Pennsylvania Act 167 Watershed Stormwater Management Plan for the Lake Erie Watershed. According to the requirements of the Commonwealth of Pennsylvania's agreement with Erie County and the County's agreement with Chester Environmental, the plan is to be completed by June 30, 1996. The total budget for the project is $323,818 (Chester Environmental, $230,082; Erie County, $93,736). Pennsylvania will reimburse the County 75 percent of the total project cost.

The County's agreement with the Commonwealth specifies the following payment schedule:

Period	Payment for Period	Cumulative Payment	Cumulative Payment (Percent of Total)
1/2/93 - 6/30/93	$ 8,550.00	$ 8,550.00	3.5
7/1/93 - 6/30/94	80,000.00	88,550.00	36.5
7/1/94 - 6/30/95	80,000.00	168,550.00	69.4
7/1/95 - 6/30/96	74,313.50	242,863.50	100.0

WORK PROGRESS AS OF SEPTEMBER 1, 1994

The following paragraphs describe our work progress and status of our charges to the project as of September 1, 1995.

600 Clubhouse Drive
Moon Township, Pennsylvania 15108
412-269-5700; Fax 412-269-5749

Task 1--Project Initiation

This task covers the administrative work required to initiate the agreements between the Pennsylvania Department of Environmental Protection (DEP), the County, and Chester Environmental.

Task 1 was completed at the inception of the project. This included meetings and negotiations with DEP, preparation of the documents required to proceed to Phase II, and execution of our contract with Erie County.

No work remains to be completed under this task.

Billings under this task total $3,536 or 99.75 percent of the budgeted total ($3,548).

Task 2--Project Coordination/Public Participation

This task consists of project coordination and reporting requirements as well as implementing a public participation program consisting of a project newsletter, meetings with the Watershed Plan Advisory Committee (WPAC), a training session, and public hearing.

Task 2 will be ongoing throughout the project. Elements of this task completed to date include conducting three Phase II WPAC meetings and issuing twelve newsletters to the WPAC members and other interested parties.

Work remaining to be completed under this task consists of the continued publication of the newsletter and conducting the remaining WPAC meetings, training session, and public hearing.

Charges under this task total $23,324 or 79.7 percent of the budgeted total ($29,264).

Task 3--Data Collection Review and Analysis

Task 3 involves the efforts required to gather, review, and analyze the basic information required to complete the technical and institutional planning steps. The following work has been completed under this task:

- Collection, review, and compilation of flood problem information from Flood Information Studies completed throughout the watershed.

- Analysis of Flood Information Studies and the extraction of data describing stream flow and velocity relationships at various locations throughout the watershed.

- Collection of rainfall data from the region and the analysis of this information to produce the determination of storm volume/duration/frequency relationships for the region.
- Compilation, review, and analysis of stream obstruction data contained in the prior plan.
- Identification, inspection, and measurement of additional obstructions as required to supplement the available information.
- Development of initial estimates of obstruction capacities.
- Collection of topographic mapping covering the area and the compilation of the hard copy topographic maps into a base map.
- Purchase of digital elevation models spanning the area.
- Preparation and distribution of municipal questionnaires.
- Compilation of the stormwater problem information contained in the municipal questionnaire responses.
- Compilation of the existing and proposed flood protection facilities information contained in the returned questionnaires.
- Contacting DEP to obtain information relative to existing and proposed flood protection facilities in the watershed.
- Compilation of the existing and proposed stormwater control facility information contained in the returned municipal questionnaires.
- Obtaining and incorporating TIGER file data into the project GIS database.
- Obtaining and incorporating the County street centerline data into the project GIS database.
- Obtaining and incorporating the Landsat Thematic Mapper Imagery into the project GIS database.
- Discussing municipal questionnaire responses at the WPAC meeting.
- Requesting streamflow monitoring records from the City of Erie.
- Collecting streamflow data from U.S.G.S records.

- Obtaining projected future land use information from Erie County.

Work under this task is essentially complete.

Charges under this task total $30,632.50 or 100 percent of the budgeted total ($30,636).

Task 4--Institutional Data Preparation

This task involves the evaluation of the municipal ordinances in order to prepare a municipal ordinance matrix. This matrix is intended to display the current stormwater management provisions contained in the various municipal ordinances. Work completed to date includes:

- Receipt of stormwater management ordinances currently in effect in the watershed.

- Preliminary review of the content of the ordinance.

- Providing the County with a sample municipal ordinance matrix to be used in compiling the matrix for the Lake Erie Area Watershed.

- Consulting with members of the staff of the Erie County Planning Department concerning procedures for the assembly of the municipal ordinance matrix.

- Receipt and analysis of the completed municipal ordinance matrix.

- Compilation of overall summary municipal stormwater management ordinance matrix.

Work remaining under this task consists essentially of final editing of the ordinance matrix and incorporation of the matrix into the plan report.

Charges under this task total $2,492 or 88.0 percent of the budgeted total ($2,832).

Task 5--Data Preparation for Technical Analysis

This task involves the engineering work necessary to transform the raw information collected in Task 3 into a form that can be directly used for the later technical tasks in the overall planning program. Work completed under this task includes the following:

- Initial classification of the satellite imagery to produce a preliminary land use classification.

- Delineation of subwatersheds and subbasins. A total of 1,603 individual subareas have been delineated.
- Digitization of the delineated subareas and incorporation of the subarea boundaries into the project GIS.
- Digital elevation models have been incorporated into the project GIS for the purpose of calculating subarea slope area characteristics.
- Digitization of the hydrologic soil group boundaries is ongoing.
- Stream segment length information has been measured and assembled for each of the 1,600 delineated subareas.
- Locations of reported stormwater problem areas have been transferred to the base maps for subsequent digitization.
- Locations of existing and proposed flood control and stormwater management facilities have been transferred to the base maps for subsequent digitization.
- The existing land cover database and GIS coverage for use in the hydrologic model have been completed.
- Locations of reported stormwater problem areas have been digitized and included in the GIS.
- Locations of existing and proposed flood control and stormwater management facilities have been digitized and included in the GIS.
- Locations of significant obstructions have been digitized into the GIS.
- Streamflow velocity information for various streams and locations throughout the watershed have been extracted from published flood information studies for use in developing travel time estimates for modeling purposes.
- Dimensional statistics have been developed for each of the 1,600 subareas.
- Digitization of the hydrologic soil group boundaries has been completed.
- The geographic information system based analyses required to develop input parameters for use in the Penn State Runoff Model have been completed.

- The County's land use projections have been incorporated into the project GIS and estimated future conditions model input parameters have been developed.

Work under this task is essentially complete with the exception of finalizing the documentation of the completed activities in the final report and appendices.

Charges under this task total $49,522.50 or 92.1 percent of the budgeted total ($53,748).

Task 6--Model Selection and Setup

Model selection and setup involve the selection and preparation of a hydrologic model appropriate for the analysis of the existing and projected land characteristics of the watershed. Work completed to date under this task includes the following:

- The Penn State Runoff Model has been selected for use on this project.

- Input data files containing the required topology and layout information have been prepared for all of the watersheds.

- The dimensions of the runoff model have been expanded to accommodate the size of the Elk Creek Watershed.

- Data describing the physical dimensions of the subareas have been incorporated into the model files.

- Testing of the model input files has been completed..

- Work regarding the determination of stream segment information and characteristics of small lakes in the watershed is completed.

- All input model files have been finalized.

Work on this task is essentially complete.

Charges to date under this task total $22,360 or 100 percent of the budgeted total ($22,368).

Task 7

Task 7 consists of the completion of the hydrologic modeling runs and the documentation of the results. Work completed under this task includes the following:

- The hydrologic model has been successfully calibrated against measured stream flows.

- Hydrologic model runs have been completed for the 2-, 5-, 10-, 25-, 50-, and 100-year return frequency 3-, 6-, 12-, and 24-hour duration storms. This modeling was completed for each of 25 separate watersheds. This entailed the completion of 600 individual model runs.

Work remaining under this task includes completion of 25-year return frequency, 24-hour duration storm model runs under future conditions.

Charges under this task total $29,896.40 or 98.2 percent of the budgeted total ($30,452).

Task 8

Task 8 consists of the analysis of the results of the modeling and data collection efforts and the development of recommended standards and criteria for the watershed. Work completed under this task includes the following:

- Selection of the design storm duration.

- Selection of the design storms return frequencies.

- Selection of the design storm temporal distribution.

- Calculation of peak discharge release rate percentages throughout the watershed.

- Identification of permissible computational techniques.

Work remaining under this task consists of the finalization of the standards and criteria based upon input received from the WPAC and the County and completion of the necessary documentation in the plan report. Charges to date total $5,499 or 66.3 percent of the budgeted amount ($8,288).

Task 9

This task consists of the assembly of the model stormwater management ordinance. As of September 1, 1995, no work had been completed on this task. However, an initial draft of the model ordinance was completed in the middle of September.

As of September 1, 1995, no charges were made to the task budget of $5,616.

Task 10--Plan Report Preparation

This task consists of the preparation of a report documenting the investigations, findings, and recommendations of the planning process. To date, the following work has been completed under this task:

- Completion of draft Section 1--Introduction.
- Completion of draft Section 2--Legal Framework for Stormwater Management.
- Completion of draft Section 3--Watershed Characteristics.
- Completion of draft Section 4--Modeling.
- Completion of draft Section 5--Development of Watershed Technical Standards and Criteria.
- Completion of draft Section 6--Stormwater Management Techniques.

Work remaining under this task consists of the preparation of the report as work progresses.

Charges to date under this task total $8,126 or 39.2 percent of the total ($21.620).

Task 11--Plan Adoption

Work under this task involves work to be performed in conjunction with securing plan adoption. This work will be completed at the close of the project.

No charges have been made to this task which has a total budget of $2,210.

Direct Costs

This category represents cost items for the purchase of data and materials, travel, mail, telephone, printing costs, and miscellaneous expenses.

Charges to date total $12,165.76 or 62.4 percent of the budgeted amount ($19,500).

STATUS OF BUDGET AND SCHEDULE

The status of our budget and progress relative to the schedule contained in our contract with the County is summarized in Figure 1. This graph compares our progress and total charges by work task to the schedule. As is indicated in Figure 1, we are essentially on schedule for all tasks through Task 8. We anticipate that we will be essentially complete with the remaining tasks, including preparation of the draft report by December 31, 1995. This will be in general accordance with our schedule with Erie County and approximately six months ahead of the June 30, 1996, completion date in the County's agreement with the Commonwealth of Pennsylvania.

We estimate that our work is approximately 85 percent complete versus a scheduled completion rate of 90 percent as of September 1, 1995. Billings to that date total $188,009.16. This represents 82 percent of our total budget. The project continues to be essentially on budget relative to progress and cost.

Please contact me at 269-5828 if you have any questions.

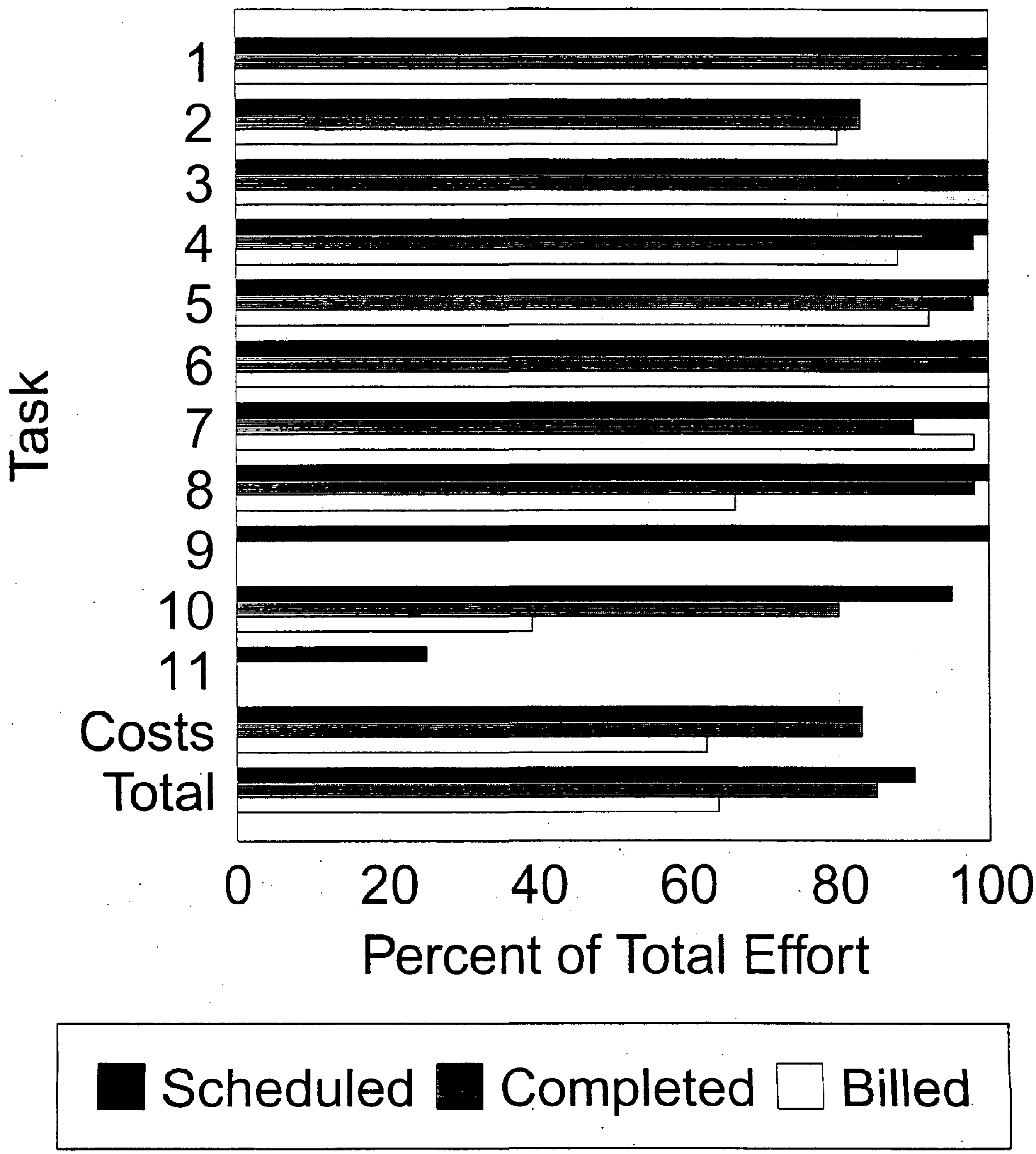
Very truly yours,

John M. Maslanik, P.E.
Technical Manager

JMM/dje/2

Enclosures

Figure 1
Status of Schedule and Budget



PART 2: NEWSLETTERS

◆Lake Erie Stormwater Management Update◆

Volume 2 Issue 5 October 1994

Lake Erie Watershed Eighteen Month Project Progress Report

Project Has Reached 18 Month Point

On March 1, 1993, Erie County authorized the initiation of an Act 167 Watershed Stormwater Management Plan for the Lake Erie Area Watershed. September 1, 1994 marked the 18 month point in the project. According to the requirements of Erie County's agreement with the Commonwealth of Pennsylvania, the plan is to be completed by June 30, 1996.

This issue of the newsletter presents a general overview of the progress that has been achieved on the Lake Erie Area Watershed Stormwater Management Plan during the initial 18 month period.

Public Participation is Ongoing

Elements of the public participation program completed to date include conducting two Watershed Plan Advisory Committee meetings and issuing ten newsletters to members of the Watershed Plan Advisory Committee and other interested parties. Public participation elements will continue throughout the project and will include additional Watershed Plan Advisory Committee meetings, continued publication of this newsletter, and a public hearing at the close of the project.

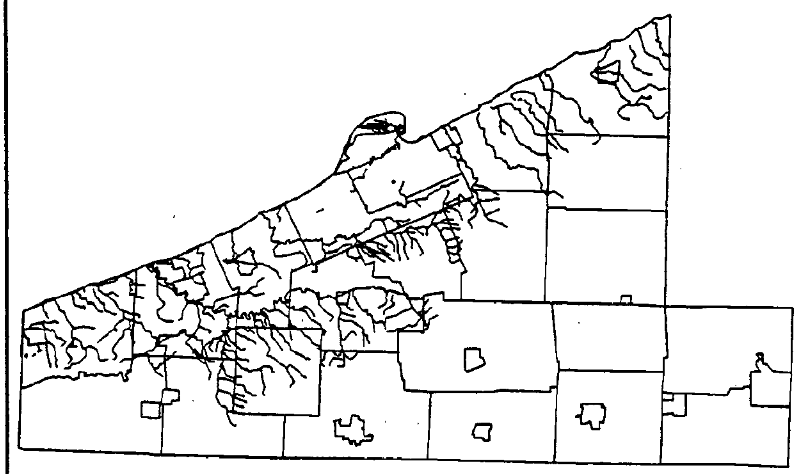


Illustration of streams comprising the Lake Erie Area Watershed (stream locations and municipal boundaries extracted from U.S. Census Bureau TIGER Files.

Data Collection Review and Analysis Activities

Data collection review and analysis activities involve efforts necessary to gather, review, and analyze the basic information required to prepare the watershed stormwater management plan. Work completed under this category of tasks includes the following:

1. Collection, review and analysis of Flood Information Studies completed throughout the watershed.

2. Collection and analysis of rainfall data and determination of storm volume, duration, and frequency relationships for the region.

3. Compilation of stream obstruction information.

4. Assembly of digital and hard copy base mapping.

5. Collection and compilation of municipal questionnaire information about stormwater problems and facilities.

6. Acquisition of satellite imagery of the area.

Data Preparation for Technical Analysis

Activities under this category involve the engineering work necessary to transform the raw data collected under the data collection phase into a form that can be directly used for technical analysis. Work completed under this category of tasks includes the following:

1. A total of 1,600 individual watersheds and subwatersheds have been delineated and their boundaries digitized.

2. Digital elevation models have been incorporated into the project geographic information system (GIS) to be used to estimate ground slopes throughout the planning area.

3. Classification of land cover classes for the purpose of estimating runoff characteristics has been completed.

4. Locations of stormwater problems and facilities have been digitized into the project GIS.

5. Dimensional statistics for each of the delineated watersheds and subwatersheds have been calculated.

Data Preparation for Technical Analysis

Model selection and setup involve the selection and preparation of a hydrologic model to be used in developing the technical stormwater management standards. Work completed under this category of tasks includes the following:

1. The Penn State Runoff Model has been selected for use on this project.

2. Input data files containing the required watershed and subwatershed topology and layout information have been prepared for all of the watersheds.

3. Testing of the model input files has begun.

4. Data describing the physical dimensions of the watersheds has been assembled into the model input files.

Summary

The project is currently on schedule in terms of progress achieved. In the coming months, work will focus on the hydrologic modeling activities and the use of the model to develop appropriate stormwater control standards. The results of these efforts will be discussed in future Watershed Plan Advisory Committee meetings.

This newsletter is published semi-monthly as a means of informing interested parties of the progress of the planning process and encouraging their input into the planning process. We encourage you to direct any questions or comments to:

Erie County Department of Planning:

Sharon L. Knoll
Erie County Court House
Erie, PA 16501
(814) 451-6336

or

Chester Environmental

John M. Maslanik
Chester Environmental
P.O. Box 15851

Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

Lake Erie Stormwater Management Update

Volume 2 Issue 6 December 1994

Overview of Hydrologic Modeling Activities

Purpose of Hydrologic Modeling

Hydrologic modeling plays two roles in stormwater management planning under Act 167. First, it provides a means to describe hydrologic conditions in the watershed and quantify the impact of existing and potential future land development activities on stormwater runoff and stream flows. Second, hydrologic modeling provides the technical basis for the selection of stormwater control standards and criteria that are appropriate for the watershed. This is particularly true for the development of specific stormwater release rate percentages as discussed in the February 1994 issue of this newsletter.

Definition of Hydrologic Modeling

The amount of stormwater runoff that results from rainfall and the rate at which the runoff moves through a watershed are affected by a number of physical factors. These factors include the volume and rate of rainfall and the physical features and characteristics of the ground upon which it falls.

Hydrologic modeling refers to computerized computational methods that are used to mathematically describe the effects of the various factors that affect rainfall - runoff relationships and produce estimates of runoff volumes and rates under a range of conditions.

The typical structure of hydrologic computer models is illustrated in Figure 1. As is indicated in Figure 1, the models generally consist of three major components:

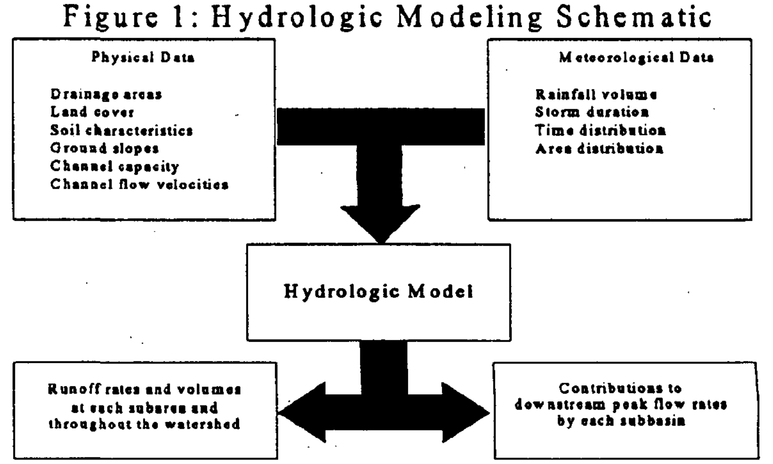
1. input data
2. the computer program
3. model output

Input data typically includes land data, stream channel data, and meteorologic data. Land data typically includes tributary area measurements and layout, soil characteristics, land cover, and ground slope. Channel data includes information describing factors that affect the capacity and time of travel of stormwater runoff through stream channels. Meteorologic data includes total precipitation and variations in rates of rainfall over time.

The computer program consists of mathematical representations of the physical factors that affect runoff rates. The hydrologic model typically contains a set of algorithms to convert rainfall on a subbasin to runoff and another set of algorithms to route the runoff from the subarea downstream through the stream channel. The algorithms are linked - output from one becomes input to another - so as to represent the integrated behavior of the watershed system.

The third part of the computer model is the output or results of the analysis. Typical output from hydrologic models includes estimates of peak flow rates, discharge hydrographs, total runoff volumes, and the contribution of flows from the each subbasins to peak flow rates experienced at downstream locations. This last output is particularly important to the determination of release rate percentages that are an important aspect of the stormwater management control standards.

Figure 1: Hydrologic Modeling Schematic



Model Selection

There are a number of hydrologic models available for use. Among the models considered for use in this watershed were the U.S. Soil Conservation Services' TR-20 model, the U.S. Army Corps of Engineers' HEC-1 model, and the Penn State Runoff Model. Of the available models, the Penn State Runoff Model has been selected for use in the Lake Erie Area watershed. The Penn State Runoff Model (PSRM) was selected for a number of reasons, including:

1. PSRM offers the ability to analyze the timing of flow contributions originating from various locations throughout the watershed. This capability is particularly important in the evaluation of the effects of various stormwater control techniques and the development of release rate percentage control standards.
2. PSRM offers flexible data input and output modes.
3. PSRM is widely accepted for use throughout Pennsylvania for the preparation of watershed wide stormwater management plans under Act 167.

Assembly of the Penn State Runoff Model

We are currently in the final stages of assembling and testing the Penn State Runoff Model representations of the Lake Erie Area Watershed. This includes the assembly of the following specific model input information:

A. Subbasin Physical Features

1. tributary land areas
2. land slopes
3. overland flow widths

B. Subbasin Hydrologic Conditions

1. runoff curve numbers
2. percentage impervious area

C. Drainage Channel Features

1. stream bankfull capacity
2. channel travel times
3. overbank flow adjustments

D. Meteorological Inputs

1. rainfall volumes
2. rainfall distributions

The information listed above has been assembled into model input files that describe the hydrologic conditions that exist in over 1,400 specific subareas that, together, form the Lake Erie Area watershed. Current activities consist of final data input file assemble and testing. Once this is completed, hydrologic modeling under a range of precipitation conditions will begin.

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Erie County Department of Planning:

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(814) 451-6336

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Chester Environmental

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Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

◆Lake Erie Stormwater Management Update◆

Volume 3 Issue 1 February 1995

Model Stormwater Management Ordinance

Role of Stormwater Management Ordinance

The ultimate purpose of stormwater management is to control surface water runoff resulting from land development activities so as to avoid the occurrence of stormwater runoff related problems such as flooding, stream erosion, and sedimentation.

Under the provisions of Act 167, the means through which this is to be accomplished is through the enforcement of local municipal ordinances that contain specific stormwater management provisions which must be satisfied by land developers. The responsibility for the adoption and subsequent enforcement of the ordinances lies with the local municipalities. Consequently, the local stormwater management ordinance provisions represent the mechanism through which the stormwater management goals are accomplished.

For this reason, one of the major elements of the Lake Erie Area Watershed Stormwater Management Plan will consist of the development of model ordinance provisions. These model ordinance provisions can be used by the local municipalities as a guide for modifying or supplementing their existing ordinances so as to include provisions that are critical to the effective implementation of stormwater management within their specific municipalities and the watershed as a whole.

Form and Content of Stormwater Ordinances

In general, stormwater management ordinance provisions can be implemented by adopting them as a single purpose ordinance or by incorporating them as amendments to to existing development ordinances (zoning and subdivision/land development ordinances). However, all stormwater management ordinances should include the following key provisions that are necessary in order to implement the performance standards and criteria of the watershed plan.

APPLICABILITY

The activities to which the provisions of the stormwater management ordinance apply must be defined.

STORMWATER PLAN REQUIREMENTS

The local ordinance should precisely describe stormwater management plan submission requirements. This includes the requirement for preparation by qualified experts and the specification of the content and the form of the information that must be included in the plan.

DESIGN STORM CHARACTERISTICS

The Stormwater Management Plan will recommend storm frequencies, durations, distributions, and associated rainfall volumes that should be used in the design of stormwater management measures (This topic was introduced in the December 1993 issue of this Newsletter). These design storm criteria should be established by the municipalities as a provision of their stormwater management ordinances.

STORMWATER MANAGEMENT CONTROL STANDARDS

The Stormwater Management Plan will recommend specific stormwater control standards that should be met by land developers in order to adequately manage stormwater runoff from their activities (This topic was introduced in the February 1994 issue of this Newsletter). The local stormwater management ordinances must specify these stormwater control standards.

METHOD OF STORMWATER CALCULATIONS

There are a wide number of methods for estimating stormwater runoff. In order to ensure that the appropriate methods are used, maintain consistency throughout the watershed, and facilitate plan review, the ordinance should specify the use of a limited number of acceptable computational techniques.

Form and Content of Stormwater Ordinances (Continued)

CONTROL TECHNIQUES

Each developer must select the technique or combination of techniques that are most appropriate to the specific site. However, the stormwater management ordinance should identify general control techniques that are proven and appropriate for use in the watershed. The developers are to use this catalog of approved techniques to select their control methodologies. The ordinance should also encourage the use of stormwater volume reduction measures where feasible. It should also contain design standards for the identified control techniques.

PLAN REVIEW PROCEDURES

The ordinance should identify the specific procedures that will be followed during the review of developers' stormwater management plan submissions.

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Erie County Department of Planning:

Sharon L. Knoll
Erie County Court House
Erie, PA 16501
(814) 451-6336

or

Chester Environmental

John M. Maslanik
Chester Environmental
600 Clubhouse Drive
Moon Township, PA 15108
(412) 269-5828

CONTINUING MAINTENANCE PROVISIONS

The ordinance should require the submission of a maintenance plan for all proposed stormwater management facilities. The ordinance should also provide for the provision of construction or performance bonds and maintenance bonds consistent with the Municipal Planning Code. The ordinance may also establish a system of financing public maintenance costs.

FEES

The municipal ordinance may provide for a fee schedule to cover the cost of reviewing developers' plan submissions.

INSPECTIONS

The ordinance should include a schedule for periodic inspections of stormwater facilities during the course of construction.

ENFORCEMENT REMEDIES AND PENALTIES

In order to enforce the provisions of the stormwater management ordinance, municipalities should incorporate into their ordinance remedies and penalties similar to those prescribed in the Municipalities Planning Code.

Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

◆Lake Erie Stormwater Management Update◆

Volume 3 Issue 2 April 1995

Review of Existing Model Ordinance Provisions Completed

The February 1995 issue of this newsletter contained a discussion of the vital role that the local municipal ordinances will play in implementing stormwater management throughout the watershed. The local ordinances will be the vehicle through which land developers are required to include effective stormwater controls into their development projects. The Lake Erie Area Watershed Stormwater Management Plan will present ordinance provisions which must be contained in the municipalities' ordinance packages in order to accomplish effective stormwater management.

As an initial step in the development and ultimate adoption of the required ordinance provisions, the Erie County Department of Planning completed a review of ordinances currently in effect in the 25 municipalities in the Lake Erie Area Watershed. The review determined what types of stormwater management provisions are contained in the existing ordinances and the general extent to which these provisions will have to be modified in order to accommodate implementation of the Lake Erie Area Watershed Stormwater Management Plan. The findings of this review will be presented in the Stormwater Management Plan document to assist municipalities in evaluating their existing ordinances in light of the plan recommendations.

The scope of the review of existing ordinances consisted of reviewing the following general types of ordinances and regulations as they exist for each of the 25 municipalities:

1. Subdivision and Land Development Ordinances and Regulations
2. Zoning Ordinances
3. Flood Damage Prevention Ordinances
4. Stormwater Management Ordinances

The ordinances were reviewed to determine the manner in which the following general categories of provisions related to stormwater management are addressed.

1. General land use planning standards
2. Stormwater control requirements
3. Specified runoff calculation methods
4. Design standards for stormwater controls
5. Erosion and sedimentation control requirements
6. Formal plan review process
7. Established basis for permitting fees
8. Specified facilities inspection schedule
9. Identified maintenance provisions

Of the 25 municipalities that are located in the watershed, 24 have adopted individual subdivision/land development ordinances, 21 have adopted zoning ordinances, and 6 have adopted stormwater management ordinances. The existing stormwater management ordinances and current subdivision and land development ordinances are the preferred locations for instituting stormwater management requirements. The fact that most of the municipalities in the watershed currently enforce one or more of these ordinances will facilitate plan implementation.

A matrix of stormwater management provisions is provided on the reverse side of this newsletter. The information contained in the matrix indicates the extent to which the required stormwater management elements are contained in the ordinances currently in force in each municipality. As the matrix indicates, several of the municipalities (the 6 with existing stormwater management ordinances) currently have provisions in effect that directly relate to specific requirements for the control of stormwater and the design of stormwater management facilities. However, in most cases the municipal ordinances are essentially silent on stormwater control issues. In all cases, amendments to the current ordinance packages will be required to implement the stormwater management plan.

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Erie County Department of Planning:
David Skellie
Erie County Court House
Erie, PA 16501
(814) 451-6336
or
Chester Environmental
John M. Maslanik
Chester Environmental
600 Clubhouse Drive
Moon Township, PA 15108

Lake Erie Area Watershed Matrix of Stormwater Ordinance Provisions

Municipality	General Runoff Control Standards	Design Storm Criteria	Runoff Calculation Method	Conveyance System Design Standards	Infiltration System Design Standards	Detention Facility Design Standards	Plan Submission Requirements	Plan Review Procedures	Maintenance Provisions	Inspection Schedule	Permitting Fees
Conneaut Township	○	○	○	○	○	○	⦶	●	○	○	○
Elk Creek Township	○	○	○	○	○	○	⦶	●	○	○	○
Erie City	○	○	○	○	○	○	⦶	●	○	○	●
Fairview Borough	○	○	○	○	○	○	⦶	●	⦶	●	●
Fairview Township	○	○	○	○	○	○	⦶	●	○	○	○
Franklin Township	○	○	○	○	○	○	⦶	●	○	○	○
Girard Borough	○	○	○	○	○	○	⦶	●	○	○	●
Girard Township	○	○	○	○	○	○	⦶	●	⦶	⦶	●
Greene Township	○	○	○	○	○	○	⦶	●	○	○	●
Greenfield Township	○	○	○	○	○	○	⦶	●	⦶	●	●
Harborcreek Township	●	●	●	⦶	○	●	●	●	●	●	●
Lake City Borough	○	○	○	○	○	○	⦶	●	⦶	⦶	●
Lawrence Park Township	○	○	○	○	○	○	⦶	●	⦶	⦶	●
McKean Borough	○	○	○	●	○	○	⦶	●	○	○	○
McKean Township	●	●	⦶	⦶	⦶	⦶	●	●	●	●	●
Millcreek Township	●	●	●	⦶	⦶	⦶	●	●	●	⦶	●
North East Borough	●	●	●	⦶	⦶	⦶	●	●	●	●	●
North East Township	●	●	⦶	⦶	⦶	⦶	●	●	●	●	●
Platea Borough	○	○	○	○	○	○	⦶	●	○	○	○
Springfield Township	○	○	○	⦶	○	○	⦶	●	○	⦶	●
Summit Township	●	●	⦶	⦶	○	○	●	●	●	●	●
Venango Township	○	○	○	○	○	○	⦶	●	○	○	●
Washington Township	⦶	⦶	○	○	○	○	⦶	●	○	○	●
Waterford Township	○	○	○	○	○	○	⦶	●	⦶	○	○
Wesleyville Borough	○	○	○	○	○	○	⦶	●	○	○	○

○ Topic not mentioned in ordinance - will require addition

⦶ Topic contained in ordinance but significant modifications will be required

● Topic contained in ordinance but will will require some modification

Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

◆Lake Erie Stormwater Management Update◆

Volume 3 Issue 3 June 1995

Overview of PENNVEST Stormwater Project Loan Program

Program Overview

PA Act 16 of 1988 has been amended to authorize the Pennsylvania Infrastructure Investment Authority (PENNVEST) to provide low interest loans to governmental units for the construction or rehabilitation of stormwater projects and best management practices to address point or nonpoint source pollution associated with stormwater. Examples of stormwater projects eligible for funding are construction of (1) new or updated storm sewer systems to eliminate stormwater flooding or to separate stormwater from sanitary sewer systems, (2) detention basins to control stormwater runoff, and (3) stormwater facilities to implement best management practices that reduce non-point source pollution.

Program Importance

This PENNVEST loan program provides low interest loans for Pennsylvania's municipalities to develop and upgrade infrastructure for stormwater drainage. This program has the following benefits:

(1) It has made it possible for municipalities to resolve storm drainage problems which are safety hazards and to separate stormwater drainage from combined sewer systems.

(2) This program supplements other PENNVEST programs which assist communities to upgrade water and sanitary sewer systems.

(3) The Commonwealth's stormwater management program is enhanced by the availability of funding to resolve existing flood problems identified in watershed stormwater management plans.

(4) Municipalities which do not regulate stormwater management for development activities in a manner consistent with the requirements of the Stormwater Management Act of 1978 are brought into compliance prior to loan approval. These municipalities must adopt implementing ordinances consistent with the Act.

Pennsylvania DER's Role

The Pennsylvania Department of Environmental Resources' staff act as technical consultants to the PENNVEST administrative staff. The Department's engineers serve as project managers for each stormwater project which is funded by PENNVEST, beginning at the planning stage and continuing through the completion of construction. The Department project managers provide engineering services which include conducting planning consultation meetings with municipalities, reviewing project plans and specifications, rating and recommending projects for PENNVEST funding, conducting interim and final construction inspections, participating in and representing the PENNVEST program at preconstruction conferences and assisting PENNVEST in conducting educational programs.

Program Funding and Budget

Funds for the loans are provided by Act 16 of 1988. These loans for stormwater projects have been available since November 10, 1993, when the PENNVEST board approved the first two loan applications. Currently, there are a total of fifteen approved loans with a cumulative loan amount of $15 million. Nine of these projects are currently under construction. In addition, there are eight pending PENNVEST stormwater project loan applications which request total funding of $2.3 million. Several other municipalities have expressed their intent to submit their loan applications for stormwater projects in 1995.

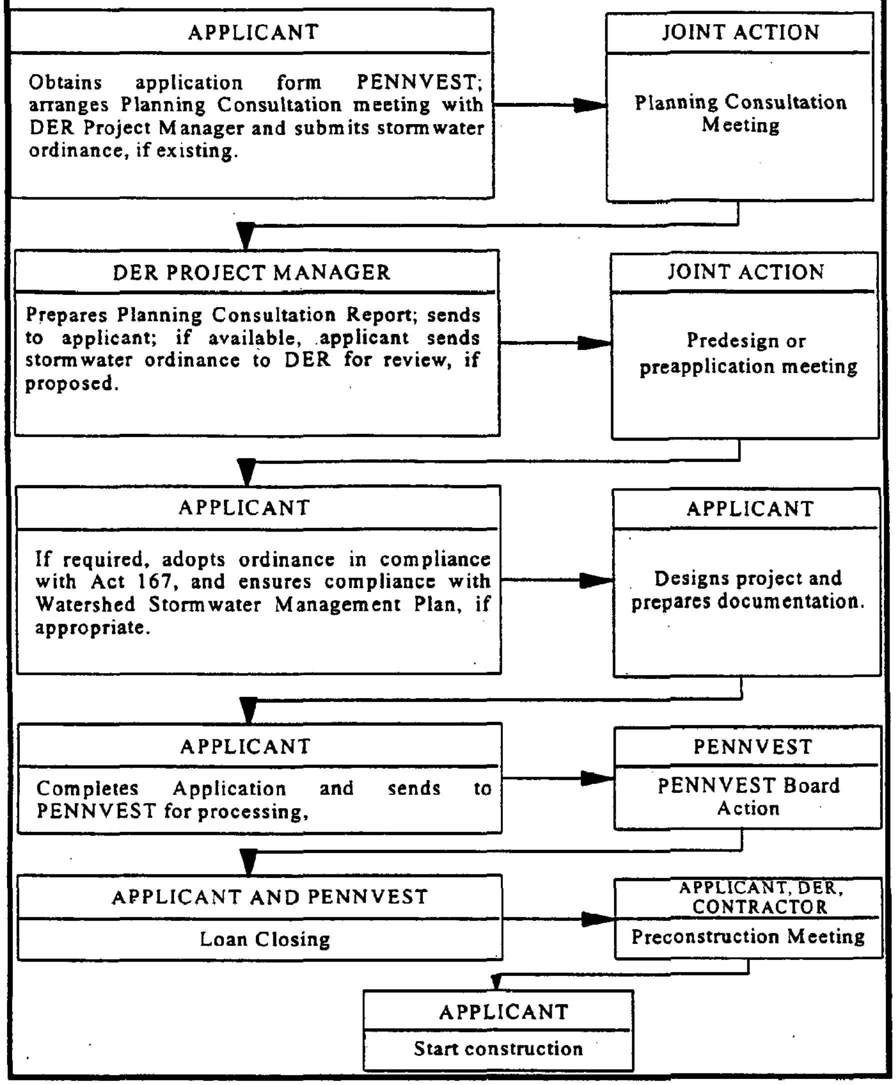
Application Process and Deadlines

The Pennsylvania Infrastructure Investment Authority has developed an established procedure for making applications for PENNVEST financial assistance. This procedure is outlined on the reverse side of this newsletter.

Pending cut-off dates for the submittal of applications are September 27, 1995, for action at the November 29, 1995, PENNVEST Board meeting and January 24, 1996, for the March 20, 1996, Board meeting. Questions concerning the PENNVEST Stormwater Program in Erie County can be addressed to:

Durla Lathia
DER
(717) 772-5661

PENNSYLVANIA INFRASTRUCTURE INVESTMENT AUTHORITY FLOW CHART FOR APPLICATION FOR FINANCIAL ASSISTANCE STORMWATER PROJECTS



This newsletter is published semi-monthly as a means of informing interested parties of the progress of the planning process and encouraging their input into the planning process. We encourage you to direct any questions or comments to:

Erie County Department of Planning:

David Skellie
Erie County Court House
Erie, PA 16501
(814) 451-6336

or

Chester Environmental

John M. Maslanik
Chester Environmental
P.O. Box 15851
Pittsburgh, PA 15244
(412) 269-5828

Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

❖Lake Erie Stormwater Management Update❖

Volume 3 Issue 4 August 1995

Preliminary Proposed Stormwater Control Criteria

Introduction

Previous issues of this newsletter have discussed the concept of stormwater control standards and criteria and their application in the Lake Erie Area Watershed. The hydrologic modeling work required to establish standards and criteria appropriate for this watershed has been completed and recommended stormwater management standards and criteria have been developed. This newsletter presents these recommended standards and criteria. They will be further discussed at a future Watershed Plan Advisory Committee meeting.

Storm Characteristics Criteria

One element of the stormwater management standards and criteria deals with describing the characteristics of the rainfall events to be used to develop the required controls. The critical rainfall event characteristics are as follows:

1. An identified duration of the particular rainfall event.
2. An identified frequency of occurrence of the storm event.
3. An identified volume or total amount of rainfall that can be expected from a particular storm.
4. An identified distribution or pattern of precipitation falling during the storm.

The following storm characteristics have been developed for use in the Lake Erie Area Watershed:

Storm Duration

The recommended storm duration for use in the watershed is the 24 hour storm. This value was selected because the hydrologic modeling indicated that, for the great majority of the subbasins in the watershed, the 24 hour duration storm created the largest peak discharge of the candidate durations tested. As a result, the use of the 24 hour storm represents an appropriate and conservative criteria.

Storm Return Frequencies

It is recommended that stormwater management facilities in the watershed should be designed to control the mean annual, 10 year, 25 year, and 100 year return frequency storms. The mean annual storm was included because this generally represents the threshold of storms producing overbank flooding. The 100 year return frequency storm event was selected because a number of identified obstructions have capacities less than the flows from storms of this magnitude, and because control of the 100 year storms will tend to preserve the flood plain and floodway boundaries as defined in completed flood insurance studies.

The intermediate 10 and 25 year return frequency storms were selected in order verify that the performance of runoff control systems will generally parallel predevelopment conditions between the upper and lower control boundary conditions.

Storm Volumes

Storm volumes associated with the 24 hour duration mean annual, 10, 25, and 100 year return frequency storms were determined from previous research to be as follows:

Mean annual storm = 2.62 inches
10 year storm = 3.75 inches
25 year storm = 4.61 inches
100 year storm = 6.19 inches

Storm Distribution

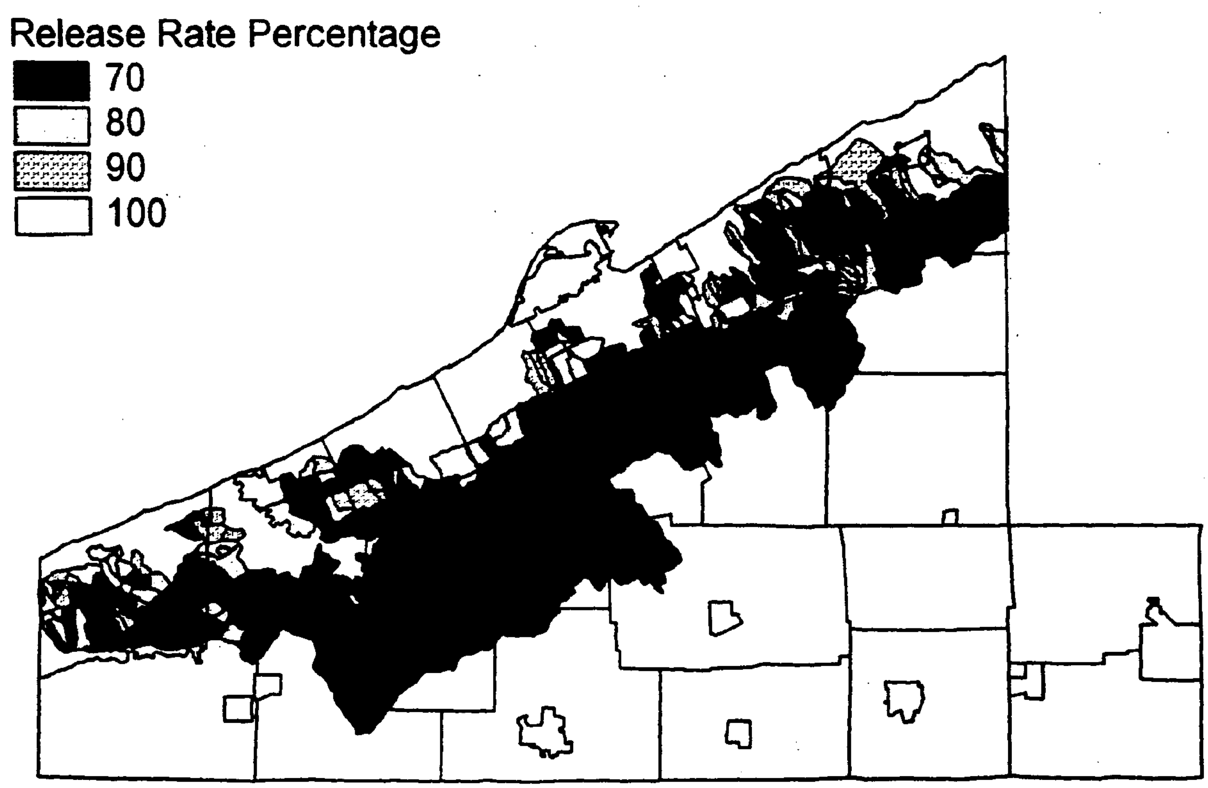
The U.S. Soil Conservation Service Type II Synthetic Storm Distribution has been selected for use in the Lake Erie Area Watershed. This storm distribution is supported by extensive research and is the distribution most frequently used in stormwater management calculations.

Runoff Control Standards

Runoff control standards refer to limits placed upon the peak rate of discharge to be permitted following completion of land development activities (post development conditions). The basic runoff control standard recommended for use in the watershed is that the peak rate of discharge from a land development site should not exceed the rate that occurred prior to development (pre-development). This minimum control standard may be waived if the municipality determines that the discharge will be made to Lake Erie or a properly designed regional stormwater control facility through adequately designed and sized stormwater conveyance facilities.

The hydrologic analysis identified areas in the watershed where adequate protection requires that further limitations to the allowable peak rate of discharge are appropriate if the developer intends to use stormwater detention techniques in order to meet the basic runoff control standard. In these areas, the post development peak rate of discharge is limited to either 70%, 80%, or 90% of the pre-development peak discharge rate. Areas of the watershed for which the use of these release rate percentages is recommended are illustrated below.

The application of the indicated release rate percentages will serve to prevent stormwater control efforts from inadvertently creating worse problems further downstream. They will also introduce a factor of safety into the regional stormwater management program.



Proposed Stormwater Runoff Control Standards Map

Erie County Department of Planning
Erie County Court House
Erie, Pennsylvania 16501

PART 3: DRAFT COPIES OF SECTIONS 3 THROUGH 6 OF THE FINAL REPORT

SECTION 3: WATERSHED CHARACTERISTICS

SECTION 4: WATERSHED TECHNICAL ANALYSIS - MODELING

SECTION 5: DEVELOPMENT OF WATERSHED TECHNICAL STANDARDS AND CRITERIA

SECTION 6: STORMWATER MANAGEMENT TECHNIQUES

LAKE ERIE AREA WATERSHED STORMWATER MANAGEMENT PLAN SECTION III WATERSHED CHARACTERISTICS

GENERAL DESCRIPTION

The designated Lake Erie Area watershed is located in Erie County in northwestern Pennsylvania. The watershed spans the northern part of the county 39 miles east to west and extends between 2.5 and 12.7 miles in a north to south direction, encompassing a total area of approximately 360 square miles along the shore of Lake Erie. The watershed includes all of the land in Erie County that drains to Lake Erie, excluding the Conneaut Creek watershed that empties into Lake Erie at Conneaut, Ohio. Portions of the watershed lie outside of Erie County in the states of New York and Ohio. A general watershed map is presented as Plate III-1.

POLITICAL FEATURES

A total of 25 Pennsylvania municipalities are situated in whole or in part within this watershed. These municipalities are listed in Table III-1.

Table III-1

Watershed Municipalities

Conneaut Township	McKean Borough
Elk Creek Township	McKean Township
Erie City	Millcreek Township
Fairview Borough	North East Borough
Fairview Township	North East Township
Franklin Township	Platea Borough
Girard Borough	Springfield Township
Girard Township	Summit Township
Greene Township	Venango Township
Greenfield Township	Washington Township
Harborcreek Township	Waterford Township
Lake City Borough	Wesleyville Borough
Lawrence Park Township	

NATURAL FEATURES

TOPOGRAPHY

The Lake Erie Area watershed lies within two physiographic provinces. The plain adjacent to Lake Erie is located in the Eastern Lake Section of the Central Lowland Province, while upland areas of the watershed are contained in the Glaciated Section of the Appalachian Plateaus Province. Each physiographic province and its respective section is separated from the other by an erosional scarp running from southwest to northeast through the County, approximately three to four miles inland from Lake Erie. The dominant topographic features of the watershed are the 47 miles of shoreline on Lake Erie and Presque Isle, which forms the bay and harbor for the City of Erie.

Except for the relatively level western third of the watershed and the three to four mile wide lake plain, the remainder of the watershed is characterized by rolling hills. The watershed is split by numerous valleys formed by erosion and containing streams that empty into Lake Erie. Elevations range from the average Lake Erie elevation of 571 feet above mean sea level to 1,550 feet above mean sea level at the southern edge of the watershed in Greenfield Township.

GEOLOGY

The bedrock of the Lake Erie Area watershed was formed from sediments deposited on the floors of ancient seas. The sedimentary rock layers underlying the county are from 6,000 to 7,500 feet thick. Shale of the Upper Devonian age underlies most of the soils, developing from layers of silt and clay alternating with thin strata of sandstone. Sandstone that was formed from sandy sediments caps some of the higher hills. With the exception of Pleistocene age sands at Presque Isle, rocks of the Pennsylvanian system are exposed in the Lake Erie Area watershed. The Cattarugus Formation of the Pennsylvanian system consists primarily of red, gray, and brown shale and sandstone. The Conneaut Group of the Cattarugus Formation includes alternating gray, brown, greenish, and purplish shales and siltstones.

Erie County was covered by at least three different glaciers, the last glaciation occurring approximately 10,000 to 15,000 years ago. As the glaciers melted and receded, they left the landscape covered with debris or glacial till that was carried from the north by the ice. The glacial till consists of a mixture of former soils and some granite, limestone, quartzite, and sandstone. The till also contains various amounts of sandstone and acid shale bedrock that was ground into fine particles by the ice. This glacial material ranges in size from clay particles to boulders.

SOILS

Soils in the Lake Erie Area watershed can be divided into two broad groups based on association with a specific parent material. These groups are soils formed in unconsolidated water sorted materials and soils formed in glacial till. The predominant soil associations in the Lake Erie Area Watershed include the following:

- Conotton-Birdsall Association
- Wayland-Chenango-Braceville Association
- Canadice-Caneadea Association
- Erie-Langford Association
- Sheffield-Platea Association
- Venango-Cambridge Association

In addition, soils can be further categorized by hydrologic groups which are determined by a soil's infiltration rate. Many factors influence infiltration rate, including physical composition, chemical composition, dominant slope, and depth of soil profile. The Soil Conservation Service (S.C.S.) has defined groups of soils having similar hydrologic properties which directly influence the volume and rate of stormwater runoff. These hydrologic soil groups are defined as follows.

Group A: Soils having a high infiltration rate, even when thoroughly wetted, and consisting of deep, well to excessively drained sands or gravels.

Group B: Soils having a moderate rate of infiltration when wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture.

Group C: Soils having a slow rate of infiltration when thoroughly wetted, consisting chiefly of soils with a layer that impedes movement of water or soils with moderately fine to fine texture.

Group D: Soils having a very slow rate of infiltration rate when wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

As the soil descriptions imply, runoff potentials increase from a minimum for Group A soils to a maximum for Group D soils. Soils along the lake plain were formed in unconsolidated water sorted materials. These soils have substrata of sands, silts, and gravel and are characterized by slow and very slow infiltration rates. Therefore, they fall in between the C and D hydrologic classes. Soils in upland areas in the central and northeastern portions of the watershed were primarily formed in glacial till. These somewhat poorly drained soils are in the C hydrologic class.

For the purposes of classifying soil types for stormwater management, this investigation identified two additional classifications: water bodies and urban land. Water bodies represent areas covered by water, a condition which results in direct runoff of precipitation. Urban land consists of land which is so altered by earth moving or so obscured by buildings or other structures that the original soils cannot be identified. In some places, cuts have removed all or nearly all the natural soil horizons. In other places, fills have buried the original soils. Urban soils are generally assigned Group C hydrologic characteristic reflecting the characteristics of the predominant natural soils in the area.

A map illustrating the distribution of soil groups throughout the watershed is provided in Plate III-2. The distribution of soil groups throughout the watershed was determined based upon soil series information mapped on the S.C.S. soil survey for Erie County. The aggregation of individual soil series into appropriate hydrologic soils groups was performed using soil classification information from S.C.S. Technical Release 55.

CLIMATE

Climatic data are available from the Weather Bureau station at Erie. The average annual temperature is about 47 degrees Fahrenheit. The mean annual freeze-free period is about

195 days, being extended by about 45 days per year by the moderating effect that the lake waters exert on the temperature. The summer mean temperature is about 67 degrees Fahrenheit and the winter mean is about 27 degrees Fahrenheit.

PRECIPITATION

Long term precipitation data is available from the Erie airport weather station. Normal annual precipitation at this station totals 39.39 inches and is well distributed throughout the year. Maximum precipitation occurs during the month of September (3.89 inches) while the minimum month in terms of precipitation is February (2.12 inches). The annual snowfall in the winter months exceeds 54 inches, with heavy snow sometimes experienced in late April. Snow is produced as polar air masses travel south over unfrozen lake waters. The air masses absorb considerable amounts of moisture in these lower levels as they move over the Great Lakes. As the warm, moistened lower air parcels reach land and rise through the cold air above, heavy snow squalls are produced that are capable of depositing 12 to 24 inches of snow on the leeward side of the lake. Lake Erie is subject to this "lake effect" snowfall during November and December. As the lake surface freezes over, snowfalls of this type become less frequent.

HYDROLOGY

The portion of the watershed covered by this plan consists of approximately ___ square miles of Erie County that drains to Lake Erie, excluding the Conneaut Creek watershed that empties into Lake Erie at Conneaut, Ohio. The designated Lake Erie Area watershed is actually a number of individual watersheds that drain into Lake Erie. The watershed also includes areas which drain directly into the lake without well defined stream channels. The major named streams and tributaries included in the Lake Erie Area watershed are listed in Table III-2.

U. S. Geological Survey Stream Gauging Stations

The United States Geological Survey (U.S.G.S.) publication *Water Resources Data for Pennsylvania* indicates that two long term, currently operating stream gauging stations are located in the Lake Erie Area watershed. The first station is located on Raccoon Creek near West Springfield on the upstream side of a highway bridge on Sanford Road. The second gauge is on Brandy Run near Girard, 100 feet upstream from a highway bridge on Tannery Road. The Raccoon Creek station has been in operation since October 1968 while the period of record for the Brandy Creek gauge dates back to May 1986. The U.S.G.S. also operates a crest gauge partial record station on Mill Creek at the 38th Street Bridge.

Table III-2

Named Streams

Cascade Creek	Mill Creek
Crooked Creek	Raccoon Creek
Eightmile Creek	Sevenmile Creek
Scott Run	Elliots Run
Elk Creek	Sixmile Creek
Brandy Run	Sixteenmile Creek
Falk Run	Baker Creek
Goodman Run	Trout Run
Halls Run	Turkey Creek
Lamson Run	Twelvemile Creek
Little Elk Creek	Twentymile Creek
Porter Run	Walnut Creek
Fourmile Creek	Bear Run
Garrison Run	Beaver Run
Marshall Run	Wilkins Run
McDannel Run	

FLOOD HAZARD / STORMWATER PROBLEM AREAS

Delineated Flood Prone Areas

Stream reaches which are identified as prone to flooding under 100 year flood conditions in Flood Insurance Studies published by the U.S. Department of Housing and Urban Development are illustrated on Plate III-3 (located in the map pocket appended to this report).

Reported Stormwater Problem Areas

The delineated flood prone areas established by flood insurance studies relate primarily to stream flooding during major storm events. As such they do not provide information concerning more minor flooding problems or stormwater problems separate from stream flooding such as street flooding, soil erosion or stormwater pollution instances.

Each of the municipalities in the watershed was contacted to solicit information relative to stormwater conditions which are perceived locally to be problems. In many cases, these problems may be somewhat localized, and related to local drainage limitations apart from stream flooding and may occur at a high frequency. Also, information relative to stormwater problems in addition to flooding (i.e., accelerated erosion, sedimentation and water pollution) was requested.

Data obtained through these efforts were supplemented by a review of Flood Insurance Studies conducted in the watershed to produce the listing of identified stormwater problem areas that is presented in Table III-3 and illustrated on Plate III-3 (located in the map pocket appended to this report). A total of 109 specific problem areas were reported in 15 of the municipalities in the watershed.

The predominant type of stormwater related problem reported by the municipalities is flooding. Over 70% of the individual problems were reported as flooding problems and additional approximately 20% of the problems were described as a combination of flooding accompanied by stream bank erosion and sedimentation. The remaining approximately 10% of the reported problems were attributed specifically to soil erosion and sedimentation.

Suggested solutions were offered for 70 of the reported problem areas. The suggested solutions include structural approaches such as constructing new or increasing the capacity of existing storm sewers, increasing the capacity of culverts, and constructing stormwater detention facilities. Also included are such remedial actions as stream dredging for the removal of accumulated silt, the clearing of debris from trash racks, culvert and bridge openings and the removal of obstructions from the stream bed. Improvements to the existing storm sewer systems are the predominant types of solutions identified (51% of the cases). Efforts to clear the stream channel are offered as a solution to existing problems is roughly 29% of the cases. Providing erosion protection, increasing stream channel capacity, and employing runoff detention basins are identified as potential solutions to a much lesser extent. All of the suggested solutions offered restore or increase hydraulic capacities. It is important to note that the ultimate success of any of these efforts will require that the incremental increases in hydraulic capacity not be offset by future increases in stormwater runoff. The nature of the problems currently encountered in the watershed and the types of solutions increase the importance of effective stormwater management in the watershed.

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
PA	Conneaut Township	No response						
PB-1	Elk Creek Township	Flooding	Little Elk Creek	Sedimentation	n/a	n/a	A, R	Stream dredging
PC-1	Erie City	Flooding	Mill Creek	Volume	> 1 per year	2 - 10	R, C	n/a
PC-2	Erie City	Flooding	Cascade Creek sanitary sewers	Volume, illegal sanitary connections	< 1 per year	> 10	R	Remove illegal connections
PC-3	Erie City	Flooding	Cascade Creek sanitary sewers	Volume, illegal sanitary connections	< 1 per year	2 - 10	R	Remove illegal connections, clean sewer
PC-4	Erie City	Flooding	Cascade Creek	Volume	< 1 per year	2 - 10	R	Change grade, increase pipe size, remove illegal connections
PC-5	Erie City	Flooding	Mill Creek combined sewers	Volume	> 1 per year	1	C	Separate sewers
PC-6	Erie City	Flooding	Unnamed	Volume, velocity	< 1 per year	n/a	n/a	n/a
PC-7	Erie City	Flooding	McDannel Run	Volume	< 1 per year	2 - 10	R	Clean mouth, upsize pipe
PD-1	Fairview Borough	Flooding, sedimentation	Trout Run	Volume, obstruction	> 1 per year	2 - 10	A, I	n/a
PD-2	Fairview Borough	Erosion	Trout Run	n/a	n/a	> 10	R, C	n/a
PD-3	Fairview Borough	Flooding, erosion,	Trout Run	Volume, velocity	> 1 per year	2 - 10	U, R	n/a
PD-4	Fairview Borough	Flooding, erosion, sedimentation, landslide	Trout Run	Volume, velocity, obstruction, direction	> 1 per year	2 - 10	U, C	n/a
PD-5	Fairview Borough	Flooding	Trout Run	Volume	> 1 per year	> 10	R, C	n/a
PD-6	Fairview Borough	Erosion, landslide	Trout Run	Volume, velocity	> 1 per year	n/a	U	n/a
PE-1	Fairview Township	Flooding	Bear Run	Obstruction	> 1 per year	2 - 10	U, A, R	Remove debris and beaver dams and realign channel
PE-2	Fairview Township	Flooding	Unnamed	Volume, direction	> 1 per year	2 - 10	R, I	Increase storm sewer sizes, use private lake as retention basin
PE-3	Fairview Township	Erosion	Trout Run	Volume, velocity, direction	< 1 per year	2 - 10	U, R	Install velocity dissipators
PE-4	Fairview Township	Flooding, erosion	Trout Run	Volume, direction	< 1 per year	2 - 10	U, R	Install storm sewer

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
PE-5	Fairview Township	Erosion	Unnamed	Velocity, direction	> 1 per year	2 - 10	R	Install storm sewer
PE-6	Fairview Township	Flooding	Unnamed	Obstruction	> 1 per year	2 - 10	R	Increase storm sewer size
PE-7	Fairview Township	Flooding	Unnamed	Volume	> 1 per year	2 - 10	R	Install storm sewers & catch basins
PE-8	Fairview Township	Flooding, erosion	Walnut Creek	Volume, obstruction	> 1 per year	> 10	R	Increase storm sewer size & install catch basins
PE-9	Fairview Township	Flooding, erosion	Walnut Creek	Volume, velocity	> 1 per year	> 10	R	Install storm sewers & catch basins
PE-10	Fairview Township	Flooding	Walnut Creek	Volume, direction, obstruction	> 1 per year	2 - 10	U, R	Remove debris and realign channel
PE-11	Fairview Township	Erosion	Porter Run	Volume, direction	> 1 per year	2 - 10	U	Install velocity dissipator, lengthen culvert, realign channel
PE-12	Fairview Township	Erosion	Elk Creek	Volume, direction	> 1 per year	2 - 10	U, A	Install velocity dissipator
PE-13	Fairview Township	Erosion	Brandy Run	Volume, velocity, direction	> 1 per year	n/a	R	Install velocity dissipator, lengthen culvert
PE-14	Fairview Township	Flooding	Trout Run	Obstruction	> 1 per year	1	Road flooding	Remove debris, install debris grate
PE-15	Fairview Township	Flooding, erosion	Unnamed	Direction	> 1 per year	2 - 10	R	Install culvert
PF-1	Franklin Township	Flooding	Little Elk Creek	Volume, obstructions	< 1 per year	n/a	n/a	n/a
PG-1	Girard Borough	No response						
PH-1	Girard Township	Flooding	Unnamed	Volume, velocity	> 1 per year	1	R	Storm sewer construction (completed)
PI	Greene Township	None reported						
PJ	Greenfield Township	No response						
PK-1	Harborcreek Township	Flooding	Fourmile Creek	Lack of maintenance of drainage way	> 1 per year	2 - 10	U, R	Improved maintenance
PK-2	Harborcreek Township	Flooding	Unnamed	Volume	> 1 per year	> 10	R	n/a
PK-3	Harborcreek Township	Flooding, erosion	Unnamed	Volume, obstruction	< 1 per year	> 10	R	Improved maintenance
PK-4	Harborcreek Township	Flooding	Sixmile Creek	Obstruction	< 1 per year	2 - 10	R	Improved maintenance
PK-5	Harborcreek Township	Flooding	Unnamed	Volume, obstruction	> 1 per year	> 10	R	n/a
PK-6	Harborcreek Township	Flooding	Sixmile Creek	Obstruction	< 1 per year	2 - 10	R	n/a

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
PK-7	Harborcreek Township	Flooding	Sixmile/Sevenmile	Volume	> 1 per year	> 10	R	Improved maintenance
PK-8	Harborcreek Township	Flooding	Unnamed	Lack of maintenance of drainage way	> 1 per year	> 10	U, R	Improved maintenance
PK-9	Harborcreek Township	Flooding	Sevenmile Creek	Volume	> 1 per year	> 10	U, R	Improved maintenance
PL-1	Lake City Borough	Erosion	Unnamed	Direction	n/a	1	n/a	n/a
PL-2	Lake City Borough	Erosion, landslide	Elk Creek	Volume, direction	n/a	1	n/a	n/a
PL-3	Lake City Borough	Flooding	Elk Creek	Volume	n/a	> 10	n/a	n/a
PL-4	Lake City Borough	n/a	Unnamed	n/a	n/a	n/a	n/a	n/a
PL-5	Lake City Borough	n/a	Unnamed	n/a	n/a	n/a	n/a	n/a
PL-6	Lake City Borough	n/a	Unnamed	n/a	n/a	n/a	n/a	n/a
PL-7	Lake City Borough	n/a	Unnamed	n/a	n/a	n/a	n/a	n/a
PL-8	Lake City Borough	Flooding	Unnamed	Volume	n/a	2 - 10	n/a	n/a
PL-9	Lake City Borough	n/a	Unnamed	n/a	n/a	> 10	n/a	n/a
PL-10	Lake City Borough	n/a	Elk Creek	Volume	n/a	1	n/a	n/a
PL-11	Lake City Borough	Flooding	Elk Creek	Volume	n/a	> 10	n/a	n/a
PL-12	Lake City Borough	Flooding, pollution	Elk Creek	Volume	n/a	> 10	n/a	n/a
PM-1	Lawrence Park Township	Flooding	Four Mile Creek	Obstruction	< 1 per year	> 10	R, C	Keep streams clear of debris, eliminate multiple bridge piers
PM-2	Lawrence Park Township	Flooding	Four Mile Creek	Obstruction	< 1 per year	1	C	Keep streams clear of debris, eliminate multiple bridge piers
PN	McKean Borough	None reported						
PO-1	McKean Township	Flooding	Elk Creek	Volume, obstruction	< 1 per year	2 - 10	U, R, C, I	n/a
PO-2	McKean Township	Flooding, erosion	Elk Creek	Volume, velocity	< 1 per year	2 - 10	R, C, I	n/a
PO-3	McKean Township	Flooding	Elk Creek	Volume	< 1 per year	2 - 10	U, A, R, C, I	n/a
PO-4	McKean Township	Flooding	Elk Creek	Volume	< 1 per year	2 - 10	A, R	n/a
PP-1	Millcreek Township	Flooding	Mill Creek	Volume, velocity	< 1 per year	1	R,C	n/a
PP-2	Millcreek Township	Flooding	Mill Creek	Volume	< 1 per year	2 - 10	Roadway	Enlarge culvert

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
PP-3	Millcreek Township	Flooding	Mill Creek	Volume	< 1 per year	2 - 10	R,C	Revamp storm sewer system
PP-4	Millcreek Township	Flooding	Mill Creek	Volume	< 1 per year	2 - 10	R	Install levees
PP-5	Millcreek Township	Flooding	Mill Creek	Volume	< 1 per year	2 - 10	R	Enlarge storm sewers
PP-6	Millcreek Township	Flooding	Mill Creek	Volume, obstruction	< 1 per year	1	R	Clear channel
PP-7	Millcreek Township	Flooding	Walnut Creek	Volume	< 1 per year	2 - 10	R	Revamp storm sewer system
PP-8	Millcreek Township	Flooding	Walnut Creek	Volume, obstruction	> 1 per year	> 10	R	Install detention facility
PP-9	Millcreek Township	Flooding	Walnut Creek	Volume, obstruction	< 1 per year	2 - 10	R	Revamp storm sewer system
PP-10	Millcreek Township	Flooding	Walnut Creek	Volume	< 1 per year	1	C	Reroute storm sewer
PP-11	Millcreek Township	Flooding	Walnut Creek	Volume	< 1 per year	2 - 10	R, C	Dredge Beaver Run
PP-12	Millcreek Township	Flooding	Walnut Creek	Volume	< 1 per year	2 - 10	R, P	Stormwater detention, revamp storm sewers
PP-13	Millcreek Township	Flooding, erosion, Landslide	Scott Run	Volume, velocity, driection, obstruction	< 1 per year	2 - 10	U, C	Improve stream channel or install storm sewers
PP-14	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	< 1 per year	> 10	R	Revamp channel and storm sewer
PP-15	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	< 1 per year	2 - 10	C	Enlarge box culvert
PP-16	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	< 1 per year	2 - 10	C	Enlarge storm sewer
PP-17	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	> 1 per year	2 - 10	R, C	Install storm sewer & add downstream capacity
PP-18	Millcreek Township	Flooding, sedimentation	Cascade Creek	Volume, obstruction	> 1 per year	2 - 10	C	Clear channel
PP-19	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	> 1 per year	2 - 10	C	Clear channel
PP-20	Millcreek Township	Flooding	Cascade Creek	Volume	< 1 per year	2 - 10	R	Install storm sewer system
PP-21	Millcreek Township	Erosion, landslide	Cascade Creek	Volume, velocity	> 1 per year	2 - 10	R, P	Stabilize slopes and channel
PP-22	Millcreek Township	Flooding	Cascade Creek	Volume, obstruction	> 1 per year	2 - 10	R	Add detention capabilities and clear obstructions from culvert
PP-23	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	< 1 per year	2 - 10	R	Provide detention & revamp storm sewer
PP-24	Millcreek Township	Flooding, erosion, sedimentation	Unnamed	Volume, velocity, obstruction	> 1 per year	2 - 10	R	Clear basin and outlet
PP-25	Millcreek Township	Flooding, sedimentation	Marshall Run	Volume, obstruction	> 1 per year	2 - 10	R	Revamp channel
PP-26	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	> 1 per year	2 - 10	R	Install storm sewer system
PP-27	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	> 1 per year	2 - 10	C	Provide detention facilities
PP-28	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	> 1 per year	> 10	R, C	Revamp storm sewer system or provide

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
								detention
PP-29	Millcreek Township	Flooding	Marshall Run	Volume, velocity	> 1 per year	2 - 10	C, I	Revamp storm sewer system or provide detention
PP-30	Millcreek Township	Erosion, sedimentation	Marshall Run	Sedimentation	> 1 per year	1	R	Clear basin and outlet structure
PP-31	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	> 1 per year	2 - 10	R	Revamp storm sewers
PP-32	Millcreek Township	Flooding	Marshall Run	Volume, velocity, obstruction	> 1 per year	n/a	Roadway	Increase storm sewer capacity
PP-33	Millcreek Township	Flooding	Marshall Run	Volume, obstruction	> 1 per year	2 - 10	R	Divert stormwater, install storm sewer
PP-34	Millcreek Township	Flooding, erosion	Marshall Run	Volume, velocity, obstruction	> 1 per year	2 - 10	C	Install debris deflector, extend storm sewer
PP-35	Millcreek Township	Erosion	Unnamed	Velocity	> 1 per year	1	R	
PP-36	Millcreek Township	Flooding	Wilkins Run	Volume, obstruction	> 1 per year	2 - 10	C	Provide drainage
PP-37	Millcreek Township	Flooding	Wilkins Run	Volume, obstruction	< 1 per year	2 - 10	C	
PP-38	Millcreek Township	Erosion	Unnamed	Volume, velocity	> 1 per year	2 - 10	R	Install storm sewers, stabilize banks
PP-39	Millcreek Township	Flooding	Unnamed	Volume	< 1 per year	2 - 10	R, C	Revamp storm sewers, install channel
PP-40	Millcreek Township	Flooding	Unnamed	Volume	< 1 per year	2 - 10	R, C	Revamp storm sewers, install channel
PP-41	Millcreek Township	Flooding	Unnamed	Volume, obstruction	< 1 per year	2 - 10	R	Revamp storm sewers
PQ	North East Borough	None reported						
PR-1	North East Township	Flooding	Sixteen Mile Creek	n/a	n/a	n/a	n/a	n/a
PR-2	North East Township	Flooding	Sixteen Mile Creek	Volume	n/a	n/a	n/a	n/a
PR-3	North East Township	Flooding	Sixteen Mile Creek	Volume	n/a	n/a	n/a	n/a
PR-4	North East Township	Flooding, erosion	Sixteen Mile Creek	Volume, obstruction	n/a	n/a	n/a	n/a
PR-5	North East Township	Flooding, erosion	Sixteen Mile Creek	Volume, obstruction	n/a	n/a	n/a	Improve driveway sluice pipes
PR-6	North East Township	Sedimentation	Sixteen Mile Creek	Volume, direction	< 1 per year	2 - 10	A,R,C	Divert flow
PS	Platea Borough	None reported						
PT	Springfield Township	No response						
PU-1	Summit Township	Flooding	Walnut Creek	Volume	> 1 per year	2 - 10	R,C	n/a

Table III-3
Summary of Reported Stormwater Problems

Map Code	Municipality	Description	Stream/Location	Reported Causes	Frequency	Number of Properties Affected	Types of Properties Affected	Proposed Solutions
PV	Venango Township	None reported						
PW	Washington Township	None reported						
PX	Waterford Township	No response						
PY-1	Wesleyville Borough	Flooding	Fourmile Creek	Volume, velocity	> 1 per year	n/a	n/a	n/a
PY-2	Wesleyville Borough	Flooding	Fourmile Creek	Volume, velocity	> 1 per year	n/a	n/a	n/a
PY-3	Wesleyville Borough	Flooding	Fourmile Creek	Volume, velocity	> 1 per year	n/a	n/a	n/a

Types of Properties Affected:

A = agricultural
C = commercial
I = industrial
R = residential
U = undeveloped

Development in Flood Hazard Areas

Stream reaches identified as being prone to flooding under 100 year storm conditions in Flood Insurance Studies are identified previously in Plate III-3. Development in the areas adjacent to these flood prone areas were characterized by analyzing the current land use within 100 feet of the identified flood prone stream reaches. This was accomplished by calculating the amounts land occupied by various land use classes that lie within the areas within 100 feet of each side of the identified stream reaches. This technique produced the approximate distribution of land use activities that lie in proximity to stream reaches identified as flood hazard areas in the Flood Insurance Studies. This information is summarized in Table III-4.

Information obtained from the watershed municipalities through the municipal questionnaire also provides an indication of the nature of development in areas affected by stormwater drainage problems. The municipalities were asked to indicate the types of properties affected by reported stormwater drainage problems and to estimated the approximate number of properties affected. Residential properties were identified as being affected by 76% of the problems for which the data was reported. Commercial properties were associated with 33% of the problems, agricultural or undeveloped in 20% of the cases, and industrial in 7% of the cases. Approximately 80% of the problems were reported to affect 10 or fewer properties and 20% were reported to affect more than 10 properties.

Table III-4

Distribution of Land Use in Flood Prone Areas

Land Use Classification	Percent of Total Area Adjacent to Flood Prone Stream Reaches
Residential	
Commercial / Industrial	
Mixed Residential / Commercial	
Agriculture	
Forest	
Barren	

STREAM OBSTRUCTIONS

Stream obstructions are defined as structures or assembly of materials which may impede, retard or change flood flows. Typical obstructions include bridge crossings, culverts, piers, suspended pipelines, etc.. Information describing the dimensions, condition and flow capacity of approximately ????????? separate stream obstructions was assembled during the preparation of this plan. The approximate locations of these obstructions are illustrated in Plate III-4 (located in the map pocket appended to this report). The prior 1981 Stormwater Management Plan served as the primary source of information describing the size and configuration of obstructions. This information was supplemented by field investigations and site visits to 77 obstruction locations.

The capacities of the obstructions were estimated based upon field measurements and the application of procedures outlined in the U. S. Department of Transportation's publication *Hydraulic Design of Highway Culverts*. The estimated capacities represent submerged but not surcharged conditions with inlet control. Calculated obstruction capacities are presented in Table A-1, located in Appendix A. Capacities are presented in terms of adequacy as compared to estimated flood peaks at each location for various flood return frequencies. The flood peaks were estimated using the PSU IV Method for estimating flood peaks in ungauged Pennsylvania streams.

FLOOD CONTROL FACILITIES

Existing and Proposed Flood Protection Facilities

The eleven existing and thirteen proposed existing flood protection facilities reported in the watershed are listed in Table III-5. The approximate locations of these facilities are illustrated in Plate III-5 (located in the map pocket accompanying this report). There are no regional flood control projects within the study area. The existing flood protection facilities are designed to provide localized flood protection and include stream channelization, stream bank protection, storm sewers and debris racks. The proposed facilities would also address localized flooding problems and include stream channel improvements, stream bank protection, and debris rack construction.

Table III-5
Reported Flood Control Projects

Map Code	Type of Flood Control Project	Status	Year Built	Owner	Reported By
FC-1	Millcreek Tube stream pipe channel	Existing	1919	Erie City	Erie City
FC-2	Garrison Run Tube stream pipe channel	Existing	1919	Erie City	Erie City
FC-3	Drift catcher (debris catcher)	Existing	Before 1915	Erie City	Erie City
FC-4	Pipe (36")	Existing	1991	Erie City	Erie City
FC-5	Storm sewer	Existing	1991	Erie City	Erie City
FC-6	Storm sewer	Existing	1991	Erie City	Erie City
FC-7	Storm sewer	Proposed	1993	Erie City	Erie City
FC-8	Pipe channel	Proposed	n/a	n/a	Fairview Borough
FC-9	Pipe channel	Proposed	1994	Fairview Twp.	Fairview Township
FC-10	Pipe channel	Proposed	1993	Fairview Twp.	Fairview Township
FC-11	Channel realignment	Proposed	1993	Private	Fairview Township
FC-12	Channel realignment	Proposed	1993	Private	Fairview Township
FC-13	Pipe channel	Proposed	1994	Fairview Twp.	Fairview Township
FC-14	Pipe channel	Proposed	1994	Fairview Twp.	Fairview Township
FC-15	Gabions	Proposed	1994	Private	Fairview Township
FC-16	Pipe channel	Proposed	1995	Fairview Twp.	Fairview Township
FC-17	Pipe channelization, riprap	Existing	1992	Private	Fairview Township
FC-18	Channel excavation, riprap	Existing	1992	Private	Fairview Township
FC-19	Creek stabilization	Proposed	n/a	Lake City Borough	Lake City Borough
FC-20	Flood walls	Existing	1940 - 1950	n/a	Lawrence Park Township
FC-21	Debris rack	Proposed	n/a	Lawrence Park Twp.	Lawrence Park Township
FC-22	Channel excavation / widening	Proposed	1996	Millcreek Township	Millcreek Township
FC-23	Retaining wall	Existing	1956	Penn DOT	Wesleyville Borough
FC-24	Bank Protection	Existing	1959	Wesleyville Borough	PA DER

STORM SEWER SYSTEMS

Existing and Future Storm Sewer Systems

The approximate locations of areas served by storm and combined sewer systems are illustrated on Plate III-5. As one would expect, the areas served by piped stormwater collection systems largely correspond to the most densely developed areas of in the watershed.

The construction of storm sewers has been identified in the municipal questionnaires as a suggested solution to stormwater drainage problems in Fairview Township, and Millcreek Township. While some storm sewer construction can be expected to occur in these and other currently developed areas in order to address localized stormwater drainage problems, most of the future storm sewer construction will occur as new areas of the watershed are developed. Therefore, future storm sewer system construction will occur as residential and commercial development progresses. The locations of such future storm sewer systems will correspond to the locations of future residential and commercial development.

Financing Storm Sewer Construction

Under current practice, storm sewer construction in currently developed areas is generally financed by the municipality in which the construction occurs. Usually, storm sewer construction in newly developing areas is financed privately by the land developer.

Amendments to the Pennsylvania Infrastructure Investment Authority (PENNVEST) make certain municipalities eligible to receive financial assistance from PENNVEST to construct stormwater management improvements. Eligible municipalities are those which are located within watersheds for which stormwater management plans have been approved by the Pennsylvania Department of Environmental Resources and which have enacted, or will enact, stormwater ordinances consistent with the approved plans. Examples of eligible stormwater projects include construction of detention / retention basins, upgrades of existing storm sewer systems and the installation of new storm sewer systems.

Municipalities considering the construction of such facilities should investigate the potential for the receipt of funding assistance through the PENNVEST program.

STORMWATER CONTROL FACILITIES

Existing and Future Stormwater Control Facilities

The survey of Lake Erie Area watershed municipalities conducted during the preparation of this plan requested information relative to current and planned stormwater control facilities. Reported stormwater control facilities are listed in Table III-6. The approximate locations of these facilities are illustrated on Plate III-5. A total of 39 and 21 proposed stormwater control facilities were reported. Nine municipalities reported either existing or proposed stormwater control facilities. Over 90 percent of the facilities reported control stormwater runoff by using detention / retention techniques. The majority of these facilities are stormwater basins or ponds. However, the use of parking lot ponding storage techniques was reported. Stormwater control through the use of facilities to induce ground water infiltration was reported in several instances. The relatively widespread use of stormwater control facilities is significant because it demonstrates that stormwater management requirements are being enforced in the watershed and indicates that the use stormwater control techniques is not foreign to developers in the area.

PRESENT AND FUTURE LAND USE

Existing land use / land cover patterns are displayed on Plate III-6 and the distribution of land cover types in the Erie County portion of the watershed is summarized in Table III-7. This information was determined based upon the analysis of satellite imagery obtained in 1993.

Table III-7

Distribution of Existing Land Use in the Watershed

Land Use Classification	Percent of Watershed Area
Residential	
Commercial / Industrial	
Mixed Residential / Commercial	
Agriculture	
Forest	
Barren	

Table III-6
Reported Stormwater Control Projects

Map Code	Type of Stormwater Control Project	Status	Year Built	Comments	Reported By
SC-1	Retention basin	Existing	1992	Existing storm system overloaded	Erie City
SC-2	Retention basin	Existing	1987		Erie City
SC-3	Dry well	Existing	1993		Erie City
SC-4	Retention basin	Existing	1987	New development to reduce flows to stream	Erie City
SC-5	Dry well	Existing	n/a		Erie City
SC-6	Dry well	Existing	n/a	Parking lot drainage	Erie City
SC-7	Retention basin	Proposed	1994		Erie City
SC-8	Retention basin	Existing	1992		Fairview Township
SC-9	Infiltration device	Proposed	1994	Perforated storm sewer	Fairview Township
SC-10	Detention/retention pond	Existing	1987	Mobile home park	Girard Township
SC-11	Detention basins	Existing	1990-1992	Behrend College	Harborcreek Township
SC-12	Detention basin	Existing	1992	Subdivision	Harborcreek Township
SC-13	Detention basin	Existing	1987	Shopping plaza	Harborcreek Township
SC-14	Detention basin	Existing	1993	Tire center	Harborcreek Township
SC-15	Infiltration basin	Existing	1990	Garden center	Harborcreek Township
SC-16	Detention basins	Proposed	1997	Subdivision	Harborcreek Township
SC-17	Detention basin	Proposed	1994	Subdivision	Harborcreek Township
SC-18	Detention basin	Proposed	1993	Commercial development	Harborcreek Township
SC-19	Detention basin	Proposed	n/a	Subdivision	Lake City Borough
SC-20	Detention basin	Proposed	n/a	Subdivision	Lake City Borough
SC-21	Detention basin	Proposed	n/a	Subdivision	Lake City Borough
SC-22	n/a	Proposed	n/a	Subdivision	Lake City Borough
SC-23	Detention basin	Proposed	n/a	Subdivision	Lake City Borough
SC-24	Underground storage	Existing	1989	Industrial	Millcreek Township
SC-25	Detention basin (dry)	Existing	1982	Subdivision	Millcreek Township
SC-26	Detention basin (dry)	Existing	1993	Subdivision	Millcreek Township
SC-27	Detention basin (dry)	Existing	1991	Subdivision	Millcreek Township
SC-28	Detention basin (dry)	Existing	1990	Subdivision	Millcreek Township
SC-29	Detention basin (dry)	Existing	1992	Subdivision	Millcreek Township
SC-30	Detention basin (dry)	Proposed	1995		Millcreek Township
SC-31	Detention basin (dry)	Proposed	1997		Millcreek Township
SC-32	Detention basin (dry)	Proposed	1997		Millcreek Township
SC-33	Detention basin (dry)	Proposed	1994		Millcreek Township
SC-34	Detention basin (dry)	Proposed	1995		Millcreek Township
SC-35	Detention basin (dry)	Proposed	1997		Millcreek Township
SC-36	Detention basin	Existing	1991	Subdivision	North East Township
SC-37	Detention basin	Existing	1993	School	North East Township
SC-38	Detention basin	Existing	1980	School	North East Township
SC-39	Detention basin	Existing	1993	Subdivision	North East Township
SC-40	Detention basin	Existing	1992	Commercial	North East Township
SC-41	Detention basin	Proposed	1994	Subdivision	North East Township
SC-42	Detention basin	Proposed	1994	Subdivision	North East Township
SC-43	Detention basin	Proposed	1994	Subdivision	North East Township
SC-44	Detention basin	Proposed	1994	Subdivision	North East Township
SC-45	Infiltration, Underground Tanks	Existing	1992	Commercial	Summit Township
SC-46	Detention basin	Existing	1990	Commercial	Summit Township
SC-47	Detention basin	Existing	1991	Commercial	Summit Township
SC-48	Underground tanks	Existing	1992	Commercial	Summit Township
SC-49	Parking lot ponding	Existing	1993	Commercial	Summit Township
SC-50	Detention basin	Existing	1990	Commercial	Summit Township
SC-51	Detention basin	Existing	1990	Church	Summit Township
SC-52	Detention basin	Existing	1993	Commercial	Summit Township
SC-53	Detention basin	Existing	1992	Subdivision	Summit Township
SC-54	Underground tanks	Existing	1993	Commercial	Summit Township
SC-55	Detention basin	Existing	1992	Commercial	Summit Township
SC-56	Detention, sedimentation ponds	Existing	1972	Landfill	Summit Township
SC-57	Detention basin	Proposed	1994	Commercial	Summit Township
SC-58	Farm pond	Existing	1960		Venango Township
SC-59	Pond	Existing	1980		Venango Township
SC-60	Pond	Existing	1986		Venango Township

High density residential, commercial and industrial land use classes predominate in the northern areas of the watershed and in the areas immediately adjacent to the Lake Erie Area. The density of commercial and residential development generally decreases as one moves southward and away from the banks of the Lake Erie Area. In the upper reaches of the south-most portions of the watershed, open space and agricultural land uses predominate.

Table III-8 contains 1990 U.S. Census population densities for each of the municipalities in the watershed. The data presented therein is indicative of the wide variation in development density in the watershed.

Table III-8

Municipality Population Densities

Municipality	Population Density (persons / sq. mi.)	Municipality	Population Density (persons / sq. mi.)
Conneaut Township	44.7	McKean Borough	697.6
Elk Creek Township	50.2	McKean Township	123.0
Erie City	4,941.7	Millcreek Township	1,587.1
Fairview Borough	1,420.0	North East Borough	3,551.5
Fairview Township	282.0	North East Township	148.2
Franklin Township	49.6	Platea Borough	141.5
Girard Borough	1,199.6	Springfield Township	85.4
Girard Township	149.0	Summit Township	221.1
Greene Township	132.2	Venango Township	51.3
Greenfield Township	52.4	Washington Township	91.0
Harborcreek Township	441.8	Waterford Township	67.9
Lake City Borough	1,399.4	Wesleyville Borough	7,.310.0
Lawrence Park Township	2,268.4		

Potential future land development patterns in the Erie County portion of the watershed were obtained from the Erie County Department of Planning. Projected future land use / land cover patterns are indicated on Plate III-7. Projected future land cover statistics are presented in Table III-9.

Table III-9

Distribution of Future Land Use in the Watershed

Land Use Classification	Percent of Watershed Area
Residential	
Commercial / Industrial	
Mixed Residential / Commercial	
Agriculture	
Forest	
Barren	

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LAKE ERIE AREA WATERSHED STORMWATER MANAGEMENT PLAN SECTION IV WATERSHED TECHNICAL ANALYSIS - MODELING

INTRODUCTION

The requirement for assessing the watershed wide impact of the implementation of stormwater runoff controls demands the use of computerized hydrologic modeling techniques to estimate stormwater runoff rates under various conditions. Digital computer modeling refers to the use of sets of mathematical expressions (algorithms) to reproduce key behavioral aspects of the natural system. This section contains a discussion of the modeling approached used in the preparation of the Lake Erie Area Watershed Stormwater Management Plan.

MODEL SELECTION

There are a number of hydrologic modeling techniques available for estimating stormwater runoff based upon ground cover and precipitation conditions. The Penn State Runoff Model (PSRM) was selected for use in the Lake Erie Area Watershed. PSRM was selected for use in this watershed for a number of reasons, including:

1. PSRM offers the ability to analyze the timing of flow combinations originating from various locations throughout a watershed. This capability is particularly important in the evaluation of the effects of various stormwater control techniques throughout a watershed.

2. PSRM is suitable for use for both urban and rural watersheds.

3. PSRM offers flexible data input and output modes.

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4. PSRM is has generally been the model of choice for use throughout Pennsylvania for the preparation of watershed stormwater management plans under Act 167.

5. Continuing development of PSRM and training in its use is supported by the Pennsylvania Department of Environmental Resources and the Pennsylvania State University.

DATA COLLECTION AND PREPARATORY ANALYSIS

Overview

Input data requirements for PSRM include the following parameters:

1. Watershed Representation Data
   - A. Tributary Area (Subbasin) Physical Features
     1. Tributary land areas
     2. Land slopes
     3. Overland flow lengths
   - B. Tributary Area (Subbasin) Hydrologic Features
     1. Composite runoff curve numbers
     2. Percentage imperviousness
     3. Initial abstraction estimates
   - C. Drainage (Reach) System Features
     1. Conveyance system (streams and conduits) capacities
     2. Conveyance system travel times
   - B. Rainfall Inputs
     1. Rainfall volumes
     2. Rainfall distribution

Subbasin Physical Features

PSRM develops runoff hydrographs for individual portions (subbasins) of a watershed which are then routed and combined in a manner corresponding to the network of streams that link the subbasins. Consequently, the initial task in the development of the modeling data base was the delineation of subbasins within the watershed. The designated Lake Erie Area watershed actually consists of a number of small to moderately sized streams which drain to Lake Erie and areas along and near the shore of the lake which drain directly to the Lake Erie essentially through overland flow. Therefore the overall watershed was first divided into subwatersheds. These subwatersheds, in turn, were further divided into subbasins. Subwatersheds were delineated based upon topographic features so as to 1) define the major stream drainage basins; and 2) accurately represent the topology of the watersheds. Delineated subwatersheds and selected characteristics are listed in Table IV-1 and delineated in Plate IV-1. Plate IV-1 is Appended to the rear of this report.

Table IV-1
Delineated Subwatersheds

Subwatershed	Drainage Area (Acres)	Subwatershed	Drainage Area (Acres)	Subwatershed	Drainage Area (Acres)
Cascade Creek	6,650	Sixmile Creek	12,220	10.0 Mile Run *	3,540
Crooked Creek	13,600	Sixteenmile Creek	12,100	11.5 Mile Run *	1,270
Eightmile Creek	4,510	Trout Run	4,080	26.9 Mile Run *	880
Elk Creek	57,960	Turkey Creek	3,440	29.0 Mile Run *	1,260
Fourmile Creek	7,280	Twelvemile Creek	9,310	39.9 Mile Run *	1,280
Garrison Run	1,360	Twentymile Creek	22,080	40.9 Mile Run *	1,340
McDaniel Run	2,000	Walnut Creek	24,430	41.5 Mile Run *	2,850
Mill Creek	8,750	3.2 Mile Run *	560	Direct Runoff	19,700
Raccoon Creek	5,000	3.9 Mile Run *	1,250		
Sevenmile Creek	5,430	6.7 Mile Run *	1,600		

* Note: Unnamed tributaries that have been designated with the distance of their mouths from the western boundary of Erie County

Subbasin boundaries comprising the modeled subwatersheds were defined so as to as closely as practical produce hydrologically homogeneous areas as well as to adequately model hydrologically significant features such as tributaries, major storm sewers, and significant obstructions. A total of 1,498 subbasins were delineated.

Subbasin boundaries comprising the modeled subwatersheds were defined so as to as closely as practical produce hydrologically homogeneous areas as well as to adequately model hydrologically significant features such as tributaries, major storm sewers, and significant obstructions. A total of 1,498 subbasins were delineated.

United States Geological Survey (U.S.G.S.) 7.5 minute quadrangle topographic mapping and local storm sewer facilities maps were used as the basis for defining subwatersheds and subbasins. The subbasin boundaries were delineated on the U.S.G.S. base and digitized to facilitate subsequent analysis. Once digitized, the subbasin areas were calculated. Subbasin areas average 133 acres in size.

Stream locations were digitized and added to the data base. Representative overland flow widths for each subbasin were calculated based upon an analysis of the digitized stream locations and subbasin boundaries.

Digital Elevation Model (DEM) data obtained from U.S.G.S. served as the source of digital terrain data used to produce slope summaries for each subbasin. DEM quadrangles were mosaicked to fully cover the watershed. Slope in percent and aspect in degrees were calculated from the raw elevation data and were used to determine representative ground slopes for each of the subbasins.

Subbasin Hydrologic Characteristics

The principal subbasin specific hydrologic characteristics of interest in this analysis are the composite Soil Conservation Service (S.C.S.) runoff curve number and percentage of impervious area for each subbasin. Percent of impervious area is defined as the percentage of the total subbasin area covered by surfaces which are essentially impermeable to water. The runoff curve number is a indication of the amount of surface runoff which may be expected to be produced as a result of a storm event. This runoff potential is influenced by land cover and soil conditions. The determination of impervious percentages and curve numbers required the classification of land cover and soil types.

Land Cover / Land Use Classification

Landsat thematic mapper multispectral digital data was used to provide the necessary land use and land cover information.

Impervious Area Statistics

Impervious area statistics for each subbasin were estimated based upon the land cover and land use through the relationships of impervious area components of various land use / land cover classes developed and published by the U.S. Soil Conservation Service.

Soils Group Classifications

The spatial distribution of soils (aggregated by S.C.S. hydrologic soil groups) was defined through the use of S.C.S. soils maps and reports for Erie County and Chautauqua County in New York. The various soil types were scan digitized into the geographic information system database. The various soil types were aggregated the appropriate hydrologic soil groups based upon U.S. Soil Conservation Service (S.C.S.) procedures. This procedure produced the data set used to create the hydrologic soil group map presented previously in Section III.

Calculation of Runoff Curve Numbers

The factors that determine runoff curve numbers (CN) are the hydrologic soil group and land cover type and condition. The S.C.S. has developed and published tables which provide runoff curve numbers for each intersection of hydrologic soil group and land cover type.

Geographic Information system (GIS) methods were used to digitally combine the land use / land cover and hydrologic soil group themes to yield a set of associations between surface type and soils units. These associations were referenced to the S.C.S. information to attach the appropriate runoff curve number. Further processing within the GIS determined composite runoff curve numbers for each of the subbasins in the watershed.

Modeling Subbasin Data File Production

All of the subbasin information necessary for PSRM modeling was represented in the GIS system as digitized themes. Once these data were resident in the GIS, the necessary analyses were performed to develop the required PSRM input data set. This data set is common to all subwatersheds and subbasins in the watershed and is keyed to assigned subbasin identification numbers. The version of PSRM used in this modeling effort has the capability of reading the appropriate individual subbasin characteristics data directly from the common subbasin data file.

Stream Reach Hydraulic Characteristics

Important input data requirements of the PSRM are estimates of the times of travel in each of the modeled stream reaches and the bankfull capacity of each reach.

Travel Time Estimates

Travel time is calculated as the length of the reach divided by the average velocity. Stream reaches were defined in conjunction with the delineation of watershed subbasins as described previously. The length of each reach was determined by direct measurement from the U.S.G.S. maps. Stream reach velocity estimates were based upon cross section information available from Flood Insurance Studies (FIS) completed within the watershed. This data was used in conjunction with empirical relationships between stream cross section measurements, discharge and mean velocity to produce velocity estimates for stream reaches for which no FIS information is available. Velocities for channelized stream segments, major storm sewers, and long culverts were calculated based upon reported and/or field measured dimensional information.

Estimated velocities were divided by measured lengths to produce estimates of times of travel for each stream reach for input into PSRM.

Bankfull Capacity Estimates

The estimation of bankfull capacities in the natural stream reaches in the Lake Erie Area watershed was performed based upon information reported in the literature which essentially states that bankfull capacities in natural streams approximate the 2-year return frequency flood discharge rate (Leopold, 1953; Brush, 1961; Harvey, 1969; and Brown, 1979). The estimates of the 2-year flood for each stream reach were using *Procedure PSU-IV for Estimating Design Flood Peaks on Ungauged Pennsylvania Watersheds*. Discharges calculated using this procedure were used as initial bankfull capacity estimates for natural stream reaches.

Full flow capacities for improved stream reaches and major storm sewer pipes or culverts were calculated based upon slope and dimensional information.

Modeling Stream Reach Data File Production

The stream reach data required for PSRM modeling of the watershed was compiled into a single reach data file. This input file contains stream time of travel and capacity data keyed to each of the identified reaches modeled during this planning effort.

Rainfall Characteristics

Rainfall Intensity-Duration-Frequency

Rainfall depth-duration-frequency (DDF) values for the Lake Erie Area watershed are summarized in Table IV-2.

These data were calculated using the charts describing rainfall intensity-duration-frequency (IDF) data presented in the Pennsylvania Department of Transportation IDF Field Manual. This document divides the state of Pennsylvania into five regions of relatively uniform rainfall patterns. Intensity-duration-frequency and depth-duration-frequency (DDF) relationships for each of the five regions are presented in the form of design charts. The Lake Erie watershed lies in Region 3.

Table IV-2
Rainfall Depth - Duration - Frequency Data

Return Period (Years)	Rainfall (3-hour)	Rainfall (6-hour)	Rainfall (12-hour)	Rainfall (24-hour)
2 - year	1.54 inches	1.84 inches	2.20 inches	2.62 inches
5 - year	1.84 inches	2.21 inches	2.65 inches	3.15 inches
10 - year	2.22 inches	2.70 inches	3.23 inches	3.75 inches
25 - year	2.54 inches	3.13 inches	3.84 inches	4.61 inches
50 - year	2.99 inches	3.68 inches	4.48 inches	5.34 inches
100 - year	3.37 inches	4.18 inches	5.14 inches	6.19 inches

Rainfall Distribution

The distribution of rainfall within the overall storm event is relevant to the modeling effort. The U.S. Soil Conservation Service (SCS) has developed synthetic rainfall distribution patterns which include maximum rainfall intensities for the selected design frequency arranged in a sequence that is critical for producing peak runoff. SCS has developed four synthetic distributions from available National Weather Service data that are applicable in various areas of the United States. The SCS Type II distribution represents design storm conditions appropriate for the region in which the Lake Erie Area Watershed is located.

Since the SCS Type II storm distribution is supported by significant research activity, is widely used in stormwater runoff calculations throughout the area and its use is incorporated directly in the frequently employed SCS stormwater runoff computational procedures it was selected for use in the Lake Erie Area Watershed model.

MODEL CALIBRATION / VERIFICATION

As was discussed in Section III, there are three gauging stations that are operated by the U.S.G.S. located in the Lake Erie Area Watershed. The gauges are located on Raccoon Creek, Brandy Run (a tributary of Elk Creek), and Mill Creek. The Mill Creek and Brandy Run gauges provide peak discharge estimates for stream flows suitable for use in calibrating the model. Peak discharge data were obtained for the Brandy Run gauge for a storm that occurred on August 28, 1990 and for the Mill Creek gauge for a storm that occurred on October 18, 1988. Hourly rainfall records for these dates as reported at the Erie Airport were also obtained.

The Penn State Runoff Model was loaded with the observed hourly rainfall records and the model peak streamflow estimates were compared to the observed results. Initial estimates for the Manning's "n" values for pervious and impervious surfaces were adjusted until optimal calibration was obtained. The model calibrated to values of 0.22 for the Manning's "n" value for pervious surfaces and 0.08 for the Manning's "n" value for impervious surfaces. The literature reports that values for Manning's "n" range from 0.03 to 0.45 for pervious surfaces ranges and from 0.01 to 0.013 for impervious surfaces.

The calibrated model estimates a peak discharge of 930 cubic feet per second (cfs) for the August 28, 1990 storm at the Brandy Run gauge. The reported gauged peak discharge for this storm is 836 cfs. The model, therefore, predicts the storm peak flow to within 11 percent of the reported value for this actual event. The model estimates a peak discharge of 2,317 cfs for the October 18, 1988 storm at the Mill Creek gauge. The reported gauged peak discharge for this storm is 2,550 cfs. The model, therefore, predicts the storm peak flow to within 9% of the reported value for this actual event. The August 28, 1990 storm produced 3.29 inches of rain over an eleven hour period. This approximates an 11 year return frequency event. The October 18, 1988 storm produced 2.89 inches of rain over a six hour period. This approximates a 16 year return frequency event. The ability of the model to predict actual observed peak discharges to within approximately 10 percent for these relatively rare events indicates acceptable model caliabration.

MODEL RESULTS

Existing Conditions

Runoff and streamflow rates were estimated under current conditions using the PSRM for each of the subwatersheds selected for detailed modeling. The model was run for the mean annual, 5, 10, 25, 50 and 100 return frequency volumes associated with 3, 6, 12 and 24 hour duration storm events. In all, model output was developed for 24 storm conditions for each of the 24 subwatersheds included in the modeling program. The results of this modeling effort are summarized in Appendix B.

In reviewing the model results, it is important to recognize that the streamflow estimates developed as part of this plan have been developed by modeling the runoff produced by rainfall volumes with a range of return frequencies distributed according to the SCS Type II Distribution. Since this distribution is designed to maximize runoff from any given rainfall volume, this procedure produces conservatively high runoff rate estimates suitable for the design of local controls. As a result, the streamflow estimates contained in Appendix B are likely to be higher that estimates produced using other methods that employ statistical analyses of reported flood frequencies.

Future Conditions

The PSRM was used to estimate runoff and streamflow rates under projected future development conditions. This was accomplished by revising the S.C.S. runoff curve number and percent impervious estimates in the model subbasin database to reflect the projected future land use / land cover characteristics as presented in Section III. The model was then run under these conditions to produce estimates of future runoff and streamflow rates for the 24 hour, 50 year return frequency storm. Model output for each of the modeled subbasins is provided in Appendix B and summarized at the mouth of each subwatershed in Table IV-3.

TABLE IV-3

COMPARISON OF EXISTING AND FUTURE PEAK DISCHARGES

(24 HOUR, 50 YEAR FREQUENCY EVENT)

DRAFT

LAKE ERIE AREA WATERSHED STORMWATER MANAGEMENT PLAN

SECTION V

DEVELOPMENT OF WATERSHED TECHNICAL STANDARDS AND CRITERIA

INTRODUCTION

As was discussed previously in Section I, the basic standard for stormwater management as established by Act 167 is that those involved in activities which can generate additional stormwater runoff, increase its velocity, or change the direction of its flow must be responsible for controlling and managing the runoff so that these changes will not cause harm to other persons or property throughout the watershed. This mandate requires comprehensive stormwater planning at a watershed level and the development of standards and criteria for managing stormwater to prevent adverse impacts, both at a particular site and anywhere downstream where the potential for harm can be reasonably be identified.

Specifically, the primary prerequisite for effective stormwater management in the watershed is the development of standards which specify allowable stormwater discharges from land development activities. Standards must also be developed which address issues associated with the control of velocity, direction and quality, if appropriate. The standards must be accompanied by associated criteria which for the basis for the design and assessment of activities instituted to comply with those standards.

CONTROL STORM CHARACTERISTICS CRITERIA

A key element in the development of this stormwater management study is the definition of the characteristics of the rainfall events against which the developed control standards must be applied. Specifically, the rainfall events which the stormwater control measures must adequately handle need to be defined. The objective of the analyses discussed in the following paragraphs was to describe characteristics of storm events which will serve as the basis for the evaluation and design of effective control measures in the Lake Erie Area Watershed.

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The critical rainfall event characteristics are as follows:

1. An identified duration or length of the particular rainfall event.
2. An identified rainfall intensity or distribution or pattern of precipitation falling over the duration of the event.
3. An identified frequency of occurrence or the expected time interval between occurrences of the given precipitation event.
4. An identified volume or total amount of rainfall that can be expected for the particular event.

Storm Distribution

The selection of the appropriate distribution of rainfall within the overall storm event was discussed in Section IV. For the reasons specified therein, the Soil Conservation Service (SCS) Type II rainfall distribution was selected for application to the development of control standards and the design of actions to be taken to satisfy those standards.

Storm Duration

Storm duration refers to the length of time over which the specified amount of precipitation falls. This factor is of concern because rainfall duration has a direct effect upon the resulting runoff volume and peak rate of discharge. The length of the rainfall period contributing to the peak runoff rate is related to the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest (time of concentration). In general, largest peak discharges result when the storm duration roughly equals the time of concentration in the watershed.

In small watersheds the critical storm duration may be measured in minutes, while in large watersheds or basins the time of concentration may be measured in days. In the Lake Erie watershed, the appropriate storm duration for use in the development and application of control standards was selected using the hydrologic model. The PSRM was used to estimated peak discharge rates throughout the watershed for the mean annual, 5, 10 25, 50 and 100 year return frequency storms of the following candidate durations: 3 hour, 6 hour, 12 hour and 24 hours. The model runs produced estimates of the peak discharges at 1438 points throughout the watershed for each of the four candidate durations. For 86% of the 1438 subbasins modeled in the watershed, the 24 hour duration storm produced the largest peak rate of discharge. The 6 hour and 3 hour storms produced the largest peak rate of discharge for 13% and 1% of the subbasins, respectively. Moveover, the 24 hour duration storm is the critical event for 22 out of the 27 modeled subwatersheds which drain approximately 95% of the study area.

A supporting consideration in the selection of the storm duration for use in the Lake Erie Area Watershed is the fact that the popular Soil Conservation Service Technical Release 55 Urban Hydrology for Small Watersheds procedure for estimating runoff and peak discharges is based upon a 24-hour storm duration. This procedure is extensively used within the region and nationally in the production of stormwater control plans for proposed land development. Adoption of a storm duration criteria other than 24 hours would effectively preclude the use of this most popular computational procedure.

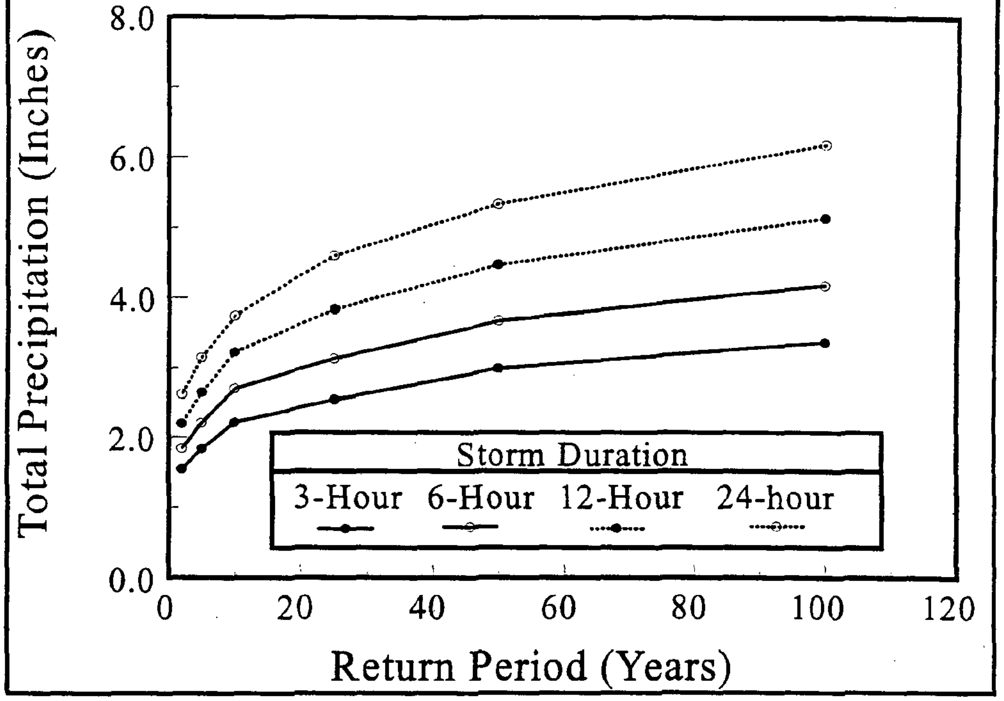
For the reasons discussed above, 24 hours has been selected as the appropriate storm duration criteria for application throughout the watershed. It is recognized that the use of shorter durations will be appropriate and permissible in the design of stormwater collection facilities. However, the selection and application of controls to the discharge of runoff from developing sites will be based upon the 24-hour storm duration criteria.

Storm Return Frequencies and Precipitation Volumes

General

Storm return frequency refers to the average interval in years over which a storm event of a given precipitation volume can be expected to recur. For example, reference to a "10-year" storm with an associated 3.75 inch 24 hour duration storm volume indicates that a storm producing 3.75 inches of rainfall over a 24 hour period on the average can be expected to occur approximately every ten years. Another way to consider this storm is that, on the average, a storm producing 3.75 inches of rainfall over a 24 hour period has approximately a ten (10) percent chance of occurring in any given year. Storm duration and volumes for return frequencies ranging from 2-years to 100-years were presented previously in Section IV of this report (Table IV-2). This data is presented graphically below in Figure V-1.

Figure V-1: Precipitation Volumes



As is indicated in Figure V-1, precipitation amounts increase with increasing return periods reflecting the obvious fact that the larger the rainfall event the more infrequent the occurrence. As one would expect, larger rainfall amounts produce larger stream discharges. This is illustrated in Figure V-2 for various streams in the watershed. The estimates of stream discharges reflected in Figure V-2 were produced using the Penn State Runoff Model developed for the Lake Erie Area Watershed.

The Pennsylvania Department of Environmental Resources "Storm Water Management Guidelines" describe design frequencies as the peak rates of discharge for which the components of drainage systems are designed. Reoccurrence intervals used for design typically range from 2 to 100 years. Individual drainage system components are generally assigned design storm frequencies based upon an evaluation of such factors as the size of the area drained and the potential for damage produced as a result of inadequate drainage as characterized by the size of the affected area, the nature and characteristics of land use in the affected area (i.e., residential, commercial, industrial uses). Components of the initial drainage system such as storm sewers and inlet structures generally a designed for relatively high frequency events ranging upwards to the 10-year storms. Major drainage system components are generally designed for less frequent, larger storms such as the 25-year and 50-year events. Flood protection projects typically are designed to accommodate conditions produced by the 100-year storm events.

Design frequency criteria for the construction of conveyance facilities such as storm sewers, pipes, culverts, bridge openings and spillways are contained in a number regulations and design manuals, including: regulations produced relative to the Pennsylvania Dam Safety and Encroachments Act, and the Pennsylvania Flood Plain Management Act; Pennsylvania Department of Transportation design criteria; Pennsylvania Soil and Erosion Control Manual; and the Water Pollution Control Federation Manual of Practice No. 9: Design and Construction of Sanitary and Storm Sewers. These references provide ample guidance under the law and standard engineering practice to permit local municipalities to establish local requirements for traditional stormwater facilities design commensurate with local conditions. There are, however, no state level criteria for stormwater discharges as they relate to total discharge volumes and rates from new land development. Moreover, unlike the generally site specific conduit construction criteria, site runoff criteria must be established based upon watershed wide considerations. Consequently, this watershed plan presents specific criteria relative to storm frequencies to be used in controlling total stormwater discharge volumes and rates from new site development.

Upper and Lower Storm Frequency Criteria Limits

For this study the design storm frequency criteria were selected to respond to watershed conditions and to meet the objective of Act 167 to minimize stormwater damage now and in the future. The following example serves to illustrate the design storm frequency criteria selection rationale. The following table contains pre-development and post-development peak rates of discharge for a hypothetical development.

Table V-1
Hypothetical Storm Discharge Rates Under Various
Return Frequency Conditions

Condition	Design Storm		
	2 - Year	10 -Year	100 - Year
Pre-development	50 cfs	75 cfs	100 cfs
Post-development	100 cfs	150 cfs	200 cfs

Two conclusions may be drawn for the data presented in this table:

1. If the design storm frequency criteria require that only the 100-year event be used as a point of control, the post-development discharge for the 2- and 10-year storms will be greater that the pre-development rate and runoff from the development may cause downstream harm at the more frequent storm events.

2. If the criteria require that only the 2-year event be applied, damage may result from increased runoff during the less frequent storm conditions.

If the stormwater conveyance system from this hypothetical development site to the river were capable of accommodating flows generated under 100-year return frequency storm conditions controlling discharges under simply a 100-year storm frequency criteria would be acceptable. However, information obtained from local municipal questionnaires and data produced through an analysis of existing obstruction capacities identified a number of locations where flooding occurs as frequently as once per year. The municipal questionnaires identified 50 locations within the watershed at which flooding occurs on average at least once per year (Table III-5). In addition, it is generally accepted that the bankfull capacity of natural stream channels approximates the mean annual flood. As a result, flows in excess of the mean annual flood frequently produce localized flooding. Consequently, the mean annual (2-year) event has been selected as the lower limit design storm frequency criteria.

The 100-year frequency storm was selected for use in the watershed for the following reasons.

1. The survey of obstructions identified 52 obstructions with capacities less than the 100-year flood (Table A-1). A failure to control runoff under storms of these frequencies would exacerbate flooding conditions at these sites as well as those sites with even smaller capacities.

2. Control of the 100-year frequency runoff would serve to preserve the 100-year flood plain and floodway boundaries as defined in the flood insurance studies completed in the watershed. These boundaries provide the basis for on-going flood plain management in the area. Permitting increased runoff at the 100-year return frequency conditions would result in an expansion of the flood zones and substantially increase the potential for damage.

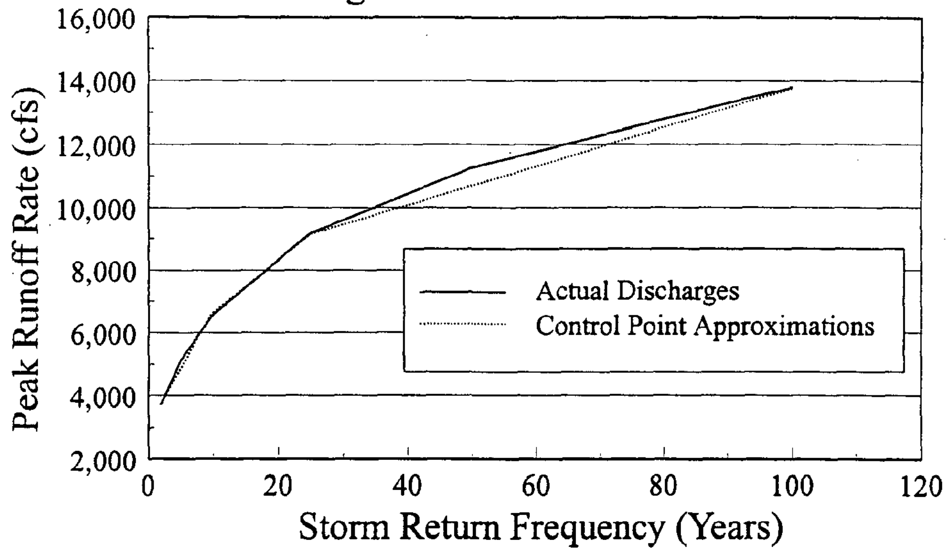
3. The use of a 100-year frequency for the upper limit of the criteria would afford a high degree of protection commensurate with the highly developed urbanized areas existing at the base of most of the watersheds.

Intermediate Frequency Criteria

In setting the upper and lower limit for return frequency storms to be controlled, it is assumed that runoff produced from discharges occurring events occurring at all intermediate frequencies will also be controlled. In other words, the stormwater control facilities would regulate discharges such that the post-development discharges would match the pre-development discharges at the 3-year, 4-year, 5-year frequency storms and so on through the 100-year frequency event. Since it would clearly be impractical to design for such a multitude of conditions and cumbersome to review management plans produced on such a basis.

Intermediate return frequency events were selected as reasonable points at which to verify that the runoff control system performance will generally parallel pre-development conditions between the 2- and 100-year limits. The selected check points and the manner in which they approximate modeled actual runoff rates at various return frequencies are illustrated in Figure V-3.

Figure V-3
Design Storm Control Points



The following storm frequency check points have been selected for inclusion in the stormwater management criteria:

1. 2-year frequency storm;
2. 10-year frequency storm;
3. 25-year frequency storm; and
4. 100-year frequency storm.

The rationale for the selection of the upper and lower check points was described previously. The reasons for selecting the 10-year and 25-year frequency storm intermediate check points are as follows:

1. The use of these two intermediate points are effective in producing a curve of runoff rate verses storm return frequency which reasonably closely

approximates the observed modeled relationship between the two variables (as illustrated in Figure V-4).

2. The 10-year and 25-year events are the most frequently referenced recommended design storm for a wide range of stormwater drainage facilities.

Precipitation Volumes

Precipitation volumes to be used in the design and evaluation of stormwater control measures in the Lake Erie Area Watershed are presented in Table V-2.

Table V-2
Design Rainfall Volumes
(24 - Hour Storm Durations)

Return Period	Volume (Inches)
2 - year	2.62
10 - year	3.75
25 - year	4.61
100 - year	6.19

RUNOFF CONTROL STANDARDS

General Approach

The basis for the establishment of runoff control standards is contained in the Storm Water Management Act. The statement of legislative findings contained in the Act (Section 2 of the Act) presents the following findings:

> "(1) Inadequate management of accelerated runoff of storm water resulting from development throughout a watershed increases flood flows and velocities, contributes to erosion and sedimentation, overtaxes the carrying capacity of streams and storm sewers, greatly increases the cost of public facilities to carry and control storm water, undermines flood plain management and flood control

> efforts in downstream communities, reduces ground water recharge, and threatens public health and safety.
>
> (2) A comprehensive program of storm water management, including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety and welfare and the protection of the people of the Commonwealth, their resources and the environment."

Section 3 of the Act defines the duty of persons engaged in the development of land as follows:

> "Any landowner and any person engaged in the alteration or development of land which may affect storm water runoff characteristics shall implement such measures consistent with the provisions of the applicable storm water plan as are reasonably necessary to prevent injury to health, safety or other property. Such measures shall include such actions as are required:
>
> (1) to assure that the maximum rate of storm water runoff is no greater after development than prior to development activities; or
>
> (2) to manage the quantity, velocity and direction of resulting storm water runoff in a manner which otherwise adequately protects health and property from possible injury."

The most effective method means of satisfying the Act based upon the statements of legislative findings and definition of duty would be to control land development activities such that both the total volume and rate of runoff from new development are identical to that which occurred before development i.e., post-development runoff volume and rates identical to pre-development conditions. If this could be accomplished, stormwater runoff from the new development would not produce any effect on downstream flows, eliminating any concern relative to the creation of downstream damage potentials.

Unfortunately, however, most land development activities involve the conversion of land use from a type which exhibits a relatively low runoff potential to a higher runoff potential type. This factor produces a typical effect upon runoff as illustrated in Figure V-4. As is indicated in Figure V-4, land development typically produces increases in both total runoff volumes and peak rates of discharge.

As is indicated in Figure V-5, measures can be taken to manage stormwater runoff by reducing the increase in total runoff volume and/or control peak rates of discharge. Techniques which may be used to minimize the increase in total runoff volume are described in Section VI of this report. These techniques generally consist of measures which minimize the extent of land cover changes from pervious to impervious areas and/or artificially induce infiltration to ground water. While these measures can be effective in reducing increases in runoff volumes, it is usually impractical to entirely avoid runoff volume increases attendant with most land development activities. Consequently, as indicated in Figure V-5, post-development hydrographs produced through the implementation of runoff volume reduction measures typically produce hydrographs with peak rates of discharge and total volumes falling between pre-development and uncontrolled post-development conditions. Because it is impractical to entirely avoid increases in total runoff volume, the inevitability of some degree of runoff volume increases must be accepted and the primary emphasis of the stormwater control criteria must be placed upon the control of peak discharge rates. In order to minimize the potential for damage, the basic, minimum stormwater runoff control criteria to be applied in the watershed is that post-development peak discharges rates must not exceed pre-development peak discharge rates. Methods of controlling peak discharge rates from new development are presented in Section VI of this report. In general, they consist of measures which essentially retain and delay the controlled release of runoff so as not to exceed pre-development rates.

The typical results of the application of peak discharge control measures in addition to feasible runoff volume reduction provisions are illustrated in Figure V-5. As is indicated in Figure V-5, although the post-development total runoff volumes fall between pre-development and uncontrolled post-development volumes, the peak rate of discharge approximates the pre-development peak rate. This is accomplished by extending the time duration of time the peak rate of discharge occurs. Instead of an instantaneous peak as occurs in the pre-development condition, the peak discharge occurs over an extended period of time. This characteristic attenuation of peak discharge rates necessitates the development of additional standards designed to avoid the development of associated downstream problems. The derivation of these supplemental standards is discussed below.

Figure V-4
Uncontrolled Runoff

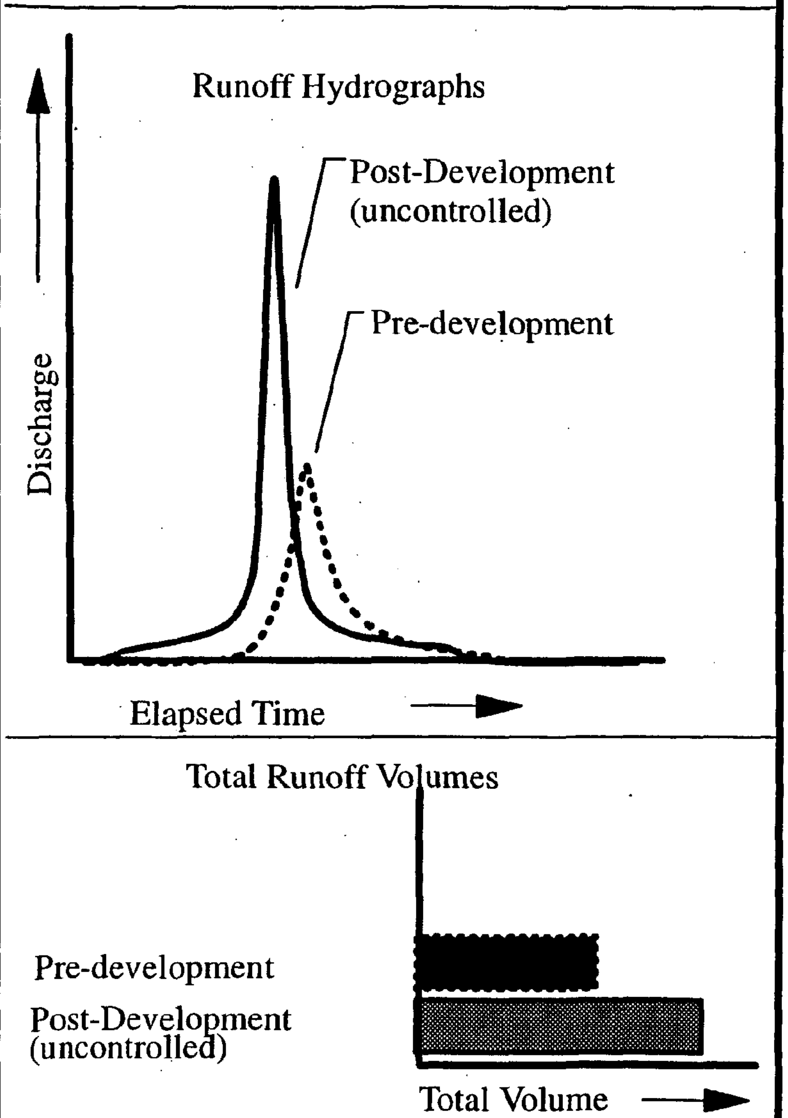
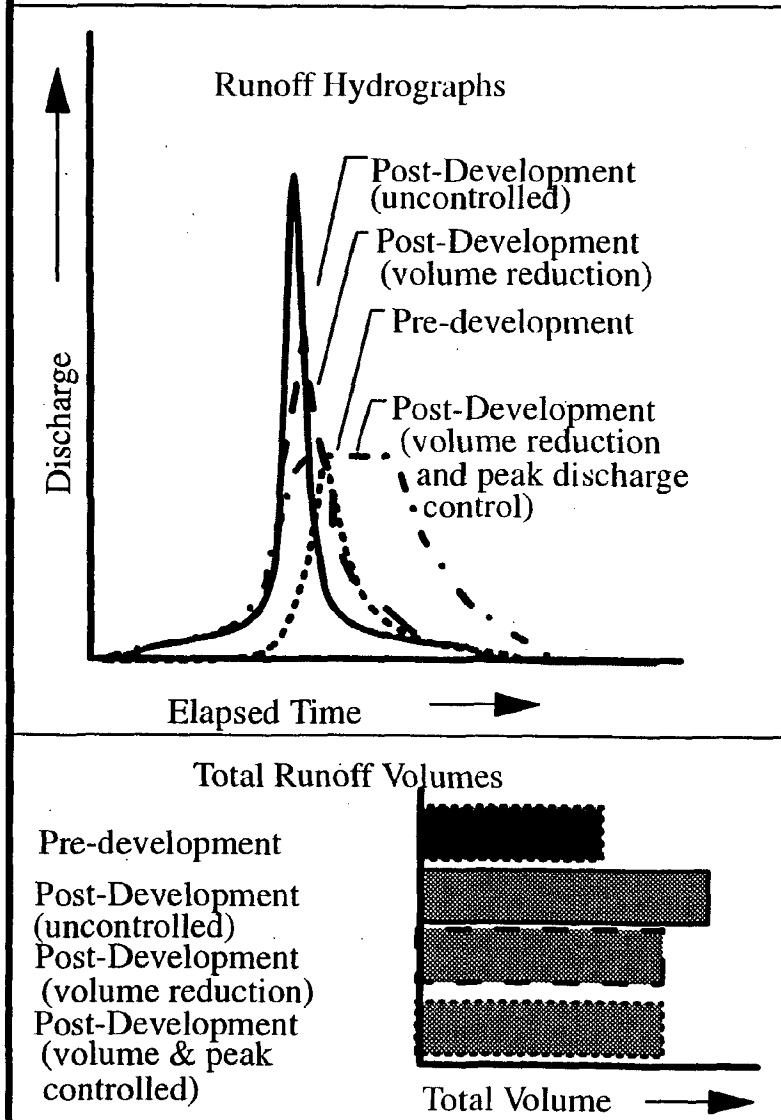


Figure V-5
Controlled Runoff



Release Rate Percentage Concept

General Concept

It is through the development and application of release rate percentage based peak discharge standards that the stormwater management plan truly assumes a watershed wide status. The investigations which serve as the basis for the establishment of release rate percentage represent the principal means through which the watershed wide implications of control strategies are evaluated, considered and incorporated into specific control standards.

The general concepts behind the development and application of release rate percentage based stormwater management criteria are discussed below through the use of the hypothetical watershed illustrated in Figure V-6. Figure V-7 contains the total hydrograph for flows at the point of interest as well as the hydrographs for flows generated in each of the five (5) subbasins as they reach the point of interest. As is illustrated in Figure V-7 and summarized in Table V-3, the peak discharge at the point of interest is sum of the discharges originating from each of the upstream subbasins as they coincidentally reach the point of interest.

Table V-3
Example Hydrograph Combination
Pre-Development Conditions

	Peak Discharge at Subbasin Mouth		Discharge at Point of Interest During Watershed Peak	
Subbasin Number	Time (Minutes)	Discharge ((cfs)	Time (Minutes)	Discharge (cfs)
1	20	200	70	0
2	50	650	70	650
3	40	500	70	400
4	50	500	70	300
5	30	300	70	150
Total	---	---	---	1,500

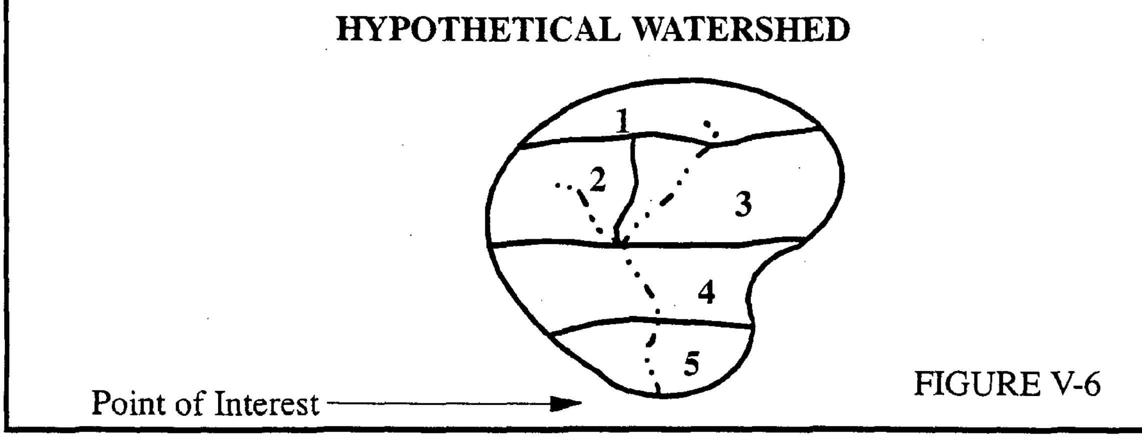


FIGURE V-6

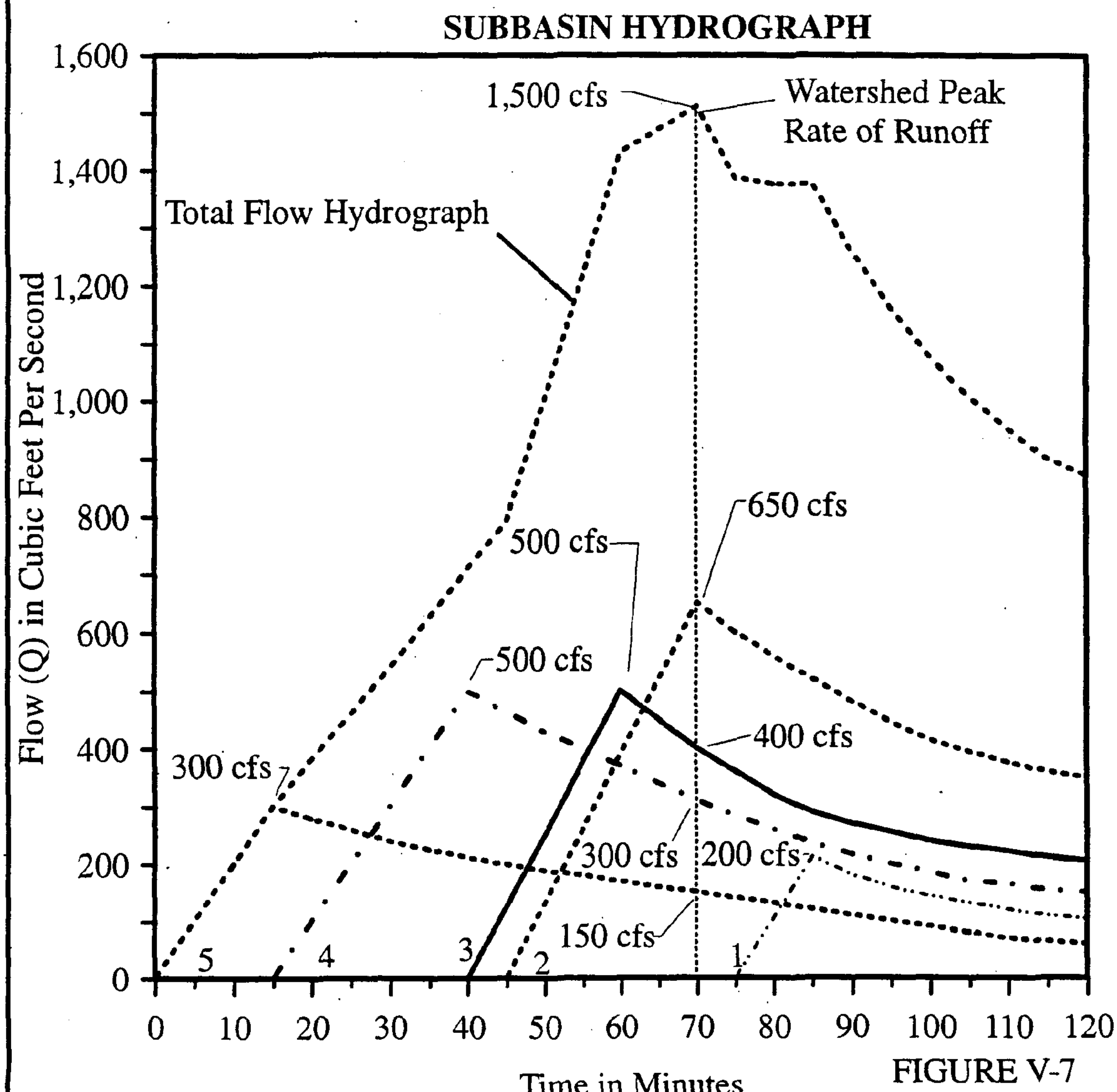


FIGURE V-7

The potential effects of land development occurring in Subbasin 3 upon the runoff hydrographs for Subbasin 3 and the entire hypothetical watershed are illustrated in Figure V-8 and are tabulated in Table V-4. Figure V-9 illustrates the effects of the institution of stormwater controls which serve to limit post-development peak discharge rates to the pre-development discharge rate through flow detention. As is indicated by the hydrographs presented in Figure V-8, limiting the peak discharge in this manner would serve to extend the period over which the pre-development discharge occurs. The result of this flow attenuation is described by the data presented in Table V-4. Following development and the institution of the specified controls, Subbasin 3 would contribute 500 cfs to the watershed peak at the point of interest rather than the 400 cfs contributed in the pre-development state. This would produce a 100 cfs increase in the watershed peak despite the control of Subbasin 3 peak discharges to pre-development levels.

Table V-4
Example Watershed Impacts of Flow Attenuation
(Subbasin 3)

Condition	Peak Runoff (cfs)	Contribution to Watershed Peak (cfs)	Watershed Peak (cfs)
Pre-development	500	400	1,500
Post-development (uncontrolled)	710	490	1,590
Post-development (100% Release Rate)	500	500	1,600
Post-development (Reduced Release Rate)	400	400	1,500

This situation can be avoided if the post-development runoff rate is controlled so that the peak rate of runoff does not exceed the rate of flow contributed to the watershed peak.

The effects of controlling peak rates of runoff in the example situation are presented graphically in Figure V-9 and in tabular form in Table V-4. As is indicated, selection of the proper allowable post-development peak discharge rate in consideration of contribution to downstream flows can avoid unintentional increases in peak stream discharges as a consequence of efforts to limit runoff from the new development(s). The methodology used to determine the allowable peak rate of post-development discharge in the previous example can be generalized as follows:

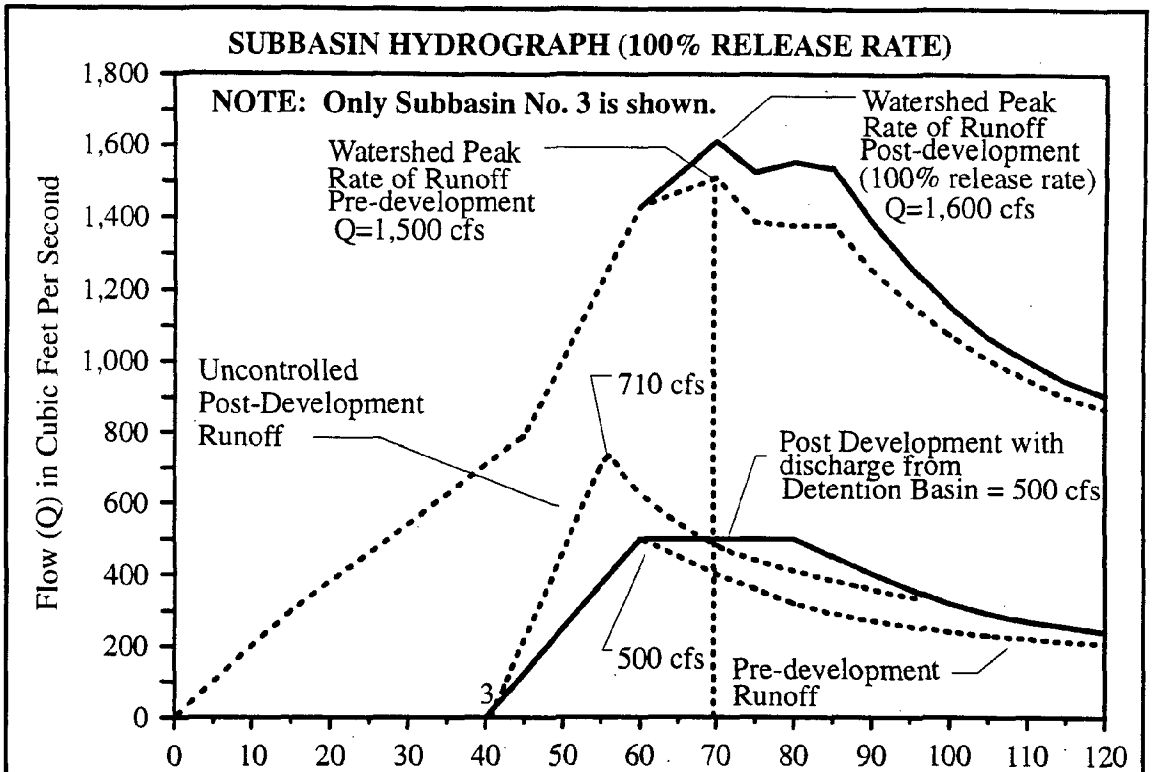


FIGURE V-8

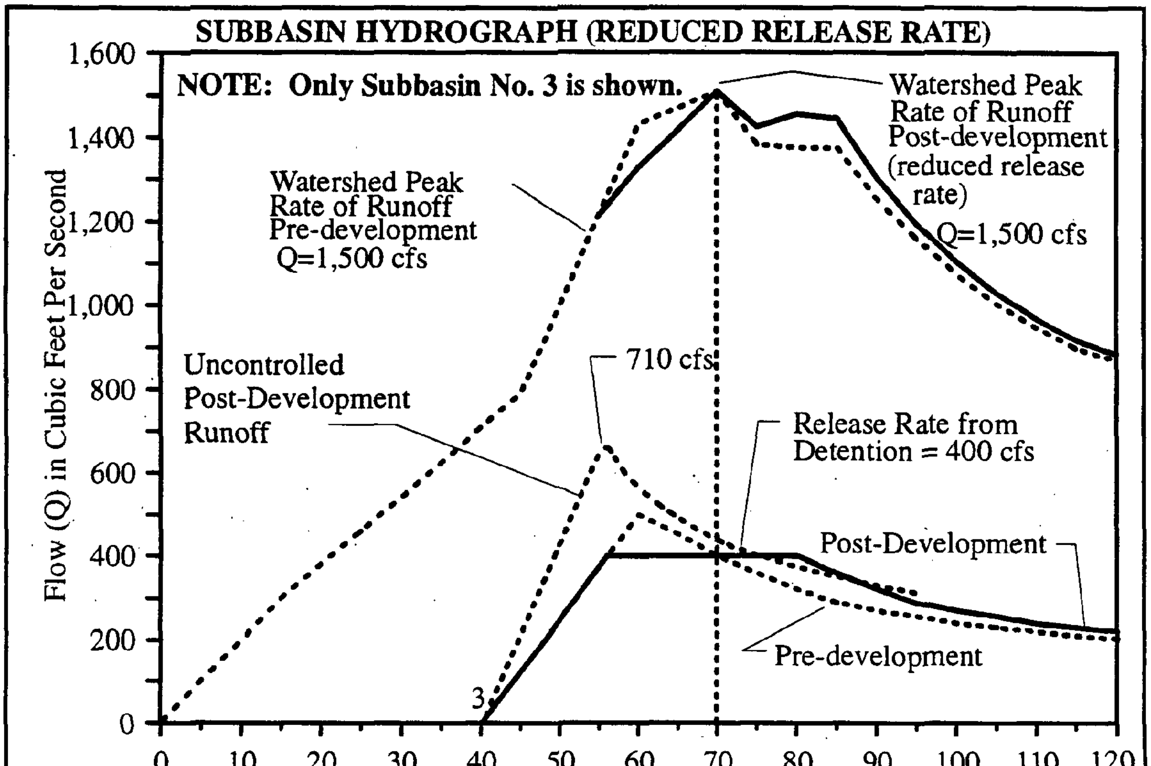


FIGURE V-9

EQUATION 1	
	Pre-development Subbasin Peak Discharge Contribution to Watershed Peak
÷	Pre-development Subbasin Peak Discharge
=	Assigned Release Rate Percentage

EQUATION 2	
	Pre-development Subbasin Peak Discharge
X	Assigned Release Rate Percentage
=	Allowable Post-development Peak Discharge

The application of these two equations to the determination of appropriate post-development peak discharge rates defines the release rate percentage concept of stormwater management. This concept was developed to be fully responsive to the intent and requirements of Pennsylvania Act 167. The release rate percentage concept provides performance standards for storm drainage control in a watershed. The significance of this approach lies in the fact that the concept provides an effective tool for comprehensive watershed stormwater management.

Determination of Release Rate Percentages

The previous paragraphs introduced the release rate percentage concept using a simplified example. The following discussion presents the general strategy that was used to apply this concept in the Lake Erie Area watershed.

The intent of the release rate percentage concept is to identify the general characteristics of subbasin interactions and combinations and define their relative impacts on total stream flows. This information is used to calculate the assigned release rate percentages as described previously. For areas modeled, the general approach employed in the Lake Erie watershed was to establish release rate percentages for each subbasin by determining the peak rate of runoff from the subbasin and its contribution to peak discharges in downstream reaches. This was accomplished using the Penn State Runoff Model described in Section IV of this report. The specific steps in the approach are as follows:

1. Perform overall watershed modeling using the Penn State Runoff Model.
2. Identify the modeled flow contribution that a particular subbasin contributes to each of the modeled downstream reaches.
3. Calculate the release rate percentage for each subbasin at each downstream reach.
4. Assign a single release rate percentage for each subbasin which will adequately protect all downstream reaches.

Areas not included in the modeling effort were assigned a release rate percentage of 100%. In these areas, which were previously identified in Chapter IV, runoff drains essentially directly to Lake Erie. Due to these circumstances, the stormwater management goals can be achieved through the application of a uniform standard requiring that post-development peaks shall not exceed the pre-development peak discharge rates (i.e., a release rate percentage of 100%).

Assigned Release Rate Percentages

Assigned release rate percentages for the Lake Erie Area watershed are tabulated in Table V-5 and illustrated in Plate V-1. Please note that in both Table V-5 and Plate V-1, the subbasins have been aggregated into "Release Rate Percentage Areas".

Application of the Assigned Release Rate Percentages

As indicated previously, the release rate percentage concept is a tool for watershed level stormwater management, developed to ensure that the application of runoff control plans for individual sites consider downstream stormwater runoff implications. As such, the release rate percentage functions as a performance standard; that is, it defines an end result which is to be attained. Under this approach, an individual developer can select and design those drainage control measures that are most appropriate to the site as long as the applicable release rate percentage for the subbasin is met. It is important to note that the assigned release rate percentages must be applied only to actions which control peak runoff through detention, retention or other methods which attenuate runoff discharges. Applicable stormwater control techniques are discussed in Section VI of this report.

Table V-5 Assigned Release Rate Precentages

In order to use the release rate for a particular site in one of the delineated release rate percentage areas, the developer should follow the following general sequence of actions.

1. Compute the pre-development and post-development runoff for the specific site using an approved method for the 2, 10, 25 and 100 year storms, using no stormwater management techniques. If the post-development peak rate is less than or equal to the pre-development rate, the requirements of Act 167 and this plan have been met. If the post-development runoff rate exceeds the pre-development rate, proceed to Step 2.

2. Apply on-site stormwater management techniques to increase infiltration and reduce impervious surfaces. Recompute the post-development runoff rate for the 2, 10, 25 and 100 year storms; and if the resulting post-development rate is less than or equal to the pre-development rate, the requirements of this plan have been met. Otherwise, stormwater detention or retention will be required and the developer should proceed to Step 3.

3. Multiply the assigned release rate percentage for the area times the pre-development peak runoff rate to determine the allowable total peak runoff rate from the development. Design the necessary detention/retention facilities to meet the allowable peak runoff rate standard.

It should be noted that stormwater storage can be provided on or off site. The possibility for regional or off-site facilities is an option which can be considered as a means to more efficiently provide the needed facilities, in terms of both cost and land requirement considerations. In many areas, the best solution may be for several development sites to share a joint facility.

Municipalities may also benefit from this approach. They may maximize development in prime development areas by providing regional or distributed storage through the use of natural or artificial lakes, floodplains and steep sloped valleys which are unsuitable for development. However, where off site storage is to be used, the developer must ensure that no flooding or harm will be caused by runoff between the new development and the off site storage area. This may require the protection of the stream channel or the construction of a storm sewer to convey runoff to the storage site.

GENERAL

A number of techniques and methods have been developed and are used to estimate rates and volumes of runoff from land. Runoff computation techniques permissible for use in developing runoff control plans pursuant to the requirements of this Plan have been identified. It is recommended that municipalities require land developers to limit the computation techniques employed to one or more of those listed. The list of permissible techniques includes a cross section of the most commonly used computation methods entailing a range of approaches, levels of effort and required access to computer facilities. The list affords developers the opportunity to select from a suite of techniques. At the same time, the number of techniques which the local reviewing engineer must be familiar with is kept to a manageable number. In addition, the use of inapplicable, unproven or inaccurate techniques is prohibited.

PERMISSIBLE RUNOFF COMPUTATION TECHNIQUES

The recommended permissible runoff computation techniques are as follows.

1. Soil Conservation Service Urban Hydrology Method (TR-55)
2. Soil Conservation Service Model (TR-20)
3. U. S. Army Corps of Engineers Flood Hydrograph Package (HEC-1)
4. Penn State Runoff Model

Engineers involved in the preparation of stormwater control plans and reviewers of such plans should review the pertinent information relative to the use and applicability of each of these methods. It is important that the assumptions implicit and explicit in each of the techniques be understood and that the techniques are properly applied.

LAKE ERIE AREA WATERSHED STORMWATER MANAGEMENT PLAN

SECTION VI STORMWATER MANAGEMENT TECHNIQUES

INTRODUCTION

One of the key features of the Stormwater Management Act 167 is its mandate to implement comprehensive stormwater runoff control practices. The Act requires stormwater planning at the watershed level in such a manner that adverse impacts of storm runoff are prevented, both at a particular site and at every potential flood prone location downstream from the watershed. Therefore, any stormwater management technique must consider runoff impacts on the watershed.

Studies in recent years have identified a number of methods of reducing the impact of development on storm peaks. Many management practices indicate the ingenuity of the planning, engineering and regulatory agencies. In particular, the publications of Soil Conservation Service (SCS) of Department of Agriculture (USDA), U.S. Environmental Protection Agency (EPA) and American Public Works Association (APWA) are quite comprehensive and aid in expanding some of the management practices reported in this section.

The present-day emphasis on detention or reduction of urban runoff within the contributing source area represents a remarkable shift in runoff control strategy that has occurred only just recently [Kibler and Aron, 1980]. This trend toward on-site runoff abatement includes control measures that either reduce the runoff directly at the source or delay the arrival of runoff contributions at some critical points downstream. Attesting to the strength of this trend is the large and growing number of publications describing various on-site control measures. Notable contributions in this regard include those by Poertner [1974, 78] on stormwater detention practices; Becker et al. [1973] on rooftop storage; Aron et al. [1976] on general runoff abatement measures including infiltration trench design; Montgomery County Soil Conservation District on storage detention ponds; ASCE, The Urban Land Institute, and the National Association of Homebuilders

[1976] on residential runoff abatement measures; and Field [1978] and Field and Lager [1975] for comprehensive reviews of structural and nonstructural measures.

Methods applicable to almost all watersheds are based on the principles of velocity reduction, infiltration enhancement, detention and retention storage, etc. However, site-specific conditions in a given watershed may lead to the development of innovative control measures. All the methods are designed to control sediment, pollution and stormwater within the watershed. Although the design of stormwater control facilities is usually completed by engineers and landscape architects, key policy questions should first be answered by local officials. Preferences of local residents concerning level of protection, aesthetics, maintenance responsibilities, and cost allocation should be assessed by local officials, not professionals. After community stormwater management policies have been established, detailed design or design review of particular controls and measures can be carried out [Clinton River Watershed Council, 1984]. Where practical, control measures should be designed to exploit the beneficial uses of the stormwater such as recreational and aesthetic benefits and recharge of underground aquifers. In many cases this can be the decisive factor in approval of a new land development. The intent of this chapter is to review the existing storm water management techniques and make recommendations on their applicability, from many different perspectives such as suitability for the study watershed, cost, effectiveness, advantages, disadvantages and maintenance etc.

CONCEPT OF STORMWATER MANAGEMENT

Early stormwater management efforts concentrated on transporting the runoff as quickly as possible from a storm location, by routing it through storm sever systems. As the urban development increased in the watershed, such a flood control effort resulted in the worst flooding conditions downstream, due to increased total flow, peak flow rate, stream velocity and flow depth. Land development causes an increase in the rate of runoff from the site, resulting in an increased peak flow rate. Changing a natural channel to a concrete-lined ditch or a storm sewer system increases the velocity and reduces the travel time to downstream locations. A reduction in the travel time may make the peak flow rate from one watershed, to contribute or in the worst case to coincide with the peak flow rate of some other watershed(s). This again results in an increased peak flow rate. Detaining the storm water and releasing the maximum rate over a longer period of time may also induce the same adverse effect.

It is now recognized due to above mentioned problems that, the most logical and effective approach to control the storm runoff is to maintain the natural runoff flow characteristics. This can be accomplished in general by maximizing natural infiltration processes, reducing impervious surfaces, preserving floodplains, and controlling storm runoff in the watershed. There are numerous, technically acceptable techniques which have varying degrees of applicability in the study area, depending on the site and watershed characteristics. Some of the most widely used ones will be described here, along with a brief discussion of their key features, advantages and disadvantages, and typical costs. It will be up to each individual developer to select the techniques that are most appropriate to the project and site. It is most likely that in most situations, a combination of on-site controls will be the most appropriate and least costly stormwater management system. Nevertheless, some alternatives must be carefully analyzed. For example, when several detention basins are used, their interaction must be considered, since a combination of the timing of their releases could aggravate downstream flooding rather than alleviating it. Also, the efficiency and costs of many of management alternatives vary from one location to another. Many of the alternatives, such as on site storage basins, erosion control, and flow reduction alternatives, may be feasible only for areas of new development [Kibler, 1982].

To determine the most appropriate set of techniques for a particular site, several factors should be evaluated:

1. Soil characteristics (i.e. soil permeability, erodibility)
2. Topography
3. Subsurface conditions
4. Drainage patterns (i.e. proximity to stream flooding problems)
5. Proposed land uses
6. Costs
7. General advantages and disadvantages of each technique.

STORMWATER RUNOFF PROBLEMS

FLOODING

During high intensity, or long duration storms the existing infiltration capacity of soils may be exceeded and surface storage filled to capacity. Once this happens, runoff occurs in the form of overland and channel flow. During some high runoff and relatively infrequent storm events, if the existing watercourses have insufficient capacity to convey surface flows, they get flooded. Natural floodplains provide some benefits by serving as reservoirs, natural recharge basins, collectors of pollutants, wildlife habitats etc. As floodplain or upstream areas are developed, this natural beneficial phenomenon, becomes a disaster due to its increased frequency and magnitude. Thus, new developments increase the flood problems and damage downstream as compared to predevelopment.

There are many ways to reduce the impact of new development on flooding. Some general concepts to consider in determining which solutions are applicable to a study area are listed below:

1. Limit development of floodplains and prohibit development in floodways
2. Increase infiltration
3. Reduce runoff rates
4. Store precipitation and runoff where it falls and release it slowly
5. Keep water confined in adequate pipes or channels
6. Protect areas subject to flood damages
7. Build flood control measures
8. Limit erosion and sediment transport

EROSION AND SEDIMENTATION

When raindrops hit bare soil, the cumulative effect is the splashing of the hundreds of tons of soil into the air. Some particles are washed into streams or downstream areas unless the velocity is very low or the soil is protected by some means. This phenomenon is called erosion. The runoff from new land developments can result in erosion both on-site and off-site. Once soil erosion begins, the soil particles transported by runoff and water currents begin to settle down in downstream drainage ways, which is called sedimentation. Sedimentation may result in blockages of natural watercourses, plugging of culverts and storm sewers, smothering of vegetation, filling of reservoirs, etc. The sedimentation occurs at increased rates during and following land development because graded areas are left in an unprotected state. Data collected by Brandt [1972] shows that erosion rates on land undergoing development can be 2,000 times the erosion rate of forested lands.

Erosion problems in the Lake Erie Area Watershed are particularly significant in the vicinity of the bluffs along the Lake Erie beach. Unless properly collected and transported, runoff in the vicinity of the bluffs can collect on the surface of the bluffs, near the crest. As the collected water percolates into the ground, it moves out through the bluff face. This excess water adds extra weight and stress to the bluff, causing erosion and extreme slumping. This ultimately can lead to loss of property and threats of damage to residential, commercial, and industrial properties.

General concepts to be followed for minimizing erosion and sedimentation include the following:

1. Protect the soil surface to withstand effects of rainfall and runoff
2. Limit soil erosion through site management practices
3. Store rainfall and runoff where it originates and release it slowly
4. Catch sediment before it enters natural drainage channels

Activities specifically appropriate to drainage in the vicinity of the shore line bluff areas include:

1. Collection of surface runoff in properly designed stormwater collection and conveyance systems.

2. Conveyance of surface water runoff to the base of the bluffs thorough outfalls equipped with energy dissipation devices.

POLLUTANT TRANSPORT

Runoff from developed areas contains more pollutants than from natural watersheds. These pollutants include heavy metals, BOD, and high concentration of suspended solids. Heavy metals and BOD generally increase as the area is developed and reach a plateau when the development has stabilized. Suspended solids increase during first two years following the disturbance of land for development. The impacts of these pollutants depend on the existing quality and use of the receiving waters. If the newly developed area drains into a supply reservoir, an increase in the amount of pollutants could be very significant. In other cases, the impacts may be difficult to determine and are often long-term, subtle, and persuasive rather than immediate.

ON-SITE STORMWATER FLOW MANAGEMENT

Many methods are available to alleviate the impact of urbanization on the quantities and rates of stormwater runoff. Maryland Interim Watershed Management Policy [APWA, 1981] states, "When engineering a site for stormwater management, two overall concepts must be considered: 1) the perviousness of the system should be maintained or enhanced, and 2) the rate of runoff should be slowed. Land development methods which tend to reduce the volume of runoff are preferred over methods which tend to increase the volume of runoff." Many of the steps taken to reduce flooding also have significant effects in reducing erosion, sedimentation and stream pollution and may reduce the need for capital-intensive storm sewer systems.

All things considered, the most advantageous means of controlling stormwater runoff from new developments is by minimizing the amount of increased runoff volumes produced. If it were possible to complete the new development in a manner such that there would be no change in either the volume or peak rate of discharge after development, there would be essentially no stormwater related impacts. While it is recognized that, in most cases, it may not be possible to accomplish the goal of making both post-development runoff volumes and peak rates of runoff match pre-development conditions, reasonable efforts should be made to minimize increases in total runoff volumes prior to the design of supplemental controls designed to control peak discharge rates.

It is recommended that land developers be encouraged to take reasonable and applicable steps to incorporate features into their developments which will serve to minimize increases in stormwater runoff volumes.

RUNOFF VOLUME REDUCTION MEASURES

Following are brief descriptions of measures which may be taken to limit increases in total runoff volumes resulting from new developments. The applicability of these measures is highly site specific and dependent upon the nature of the development. However, it is recognized that the potential application of these techniques be seriously considered early in the design of land development activities.

Limit the Amount of Land Disturbed

The added volume of runoff produced as a result of the development of "virgin" land is directly related to the amount of land cover changed from its natural state to a more impervious condition (usually paved). Consequently, increases in runoff volumes can be minimized to the extent that land cover disturbances can be minimized. Individuals involved in land development activities, should, therefore, be encouraged to optimize their development activities from the standpoint of accomplishing the basic objectives of the development while minimizing the amount of paved areas used and natural areas disturbed.

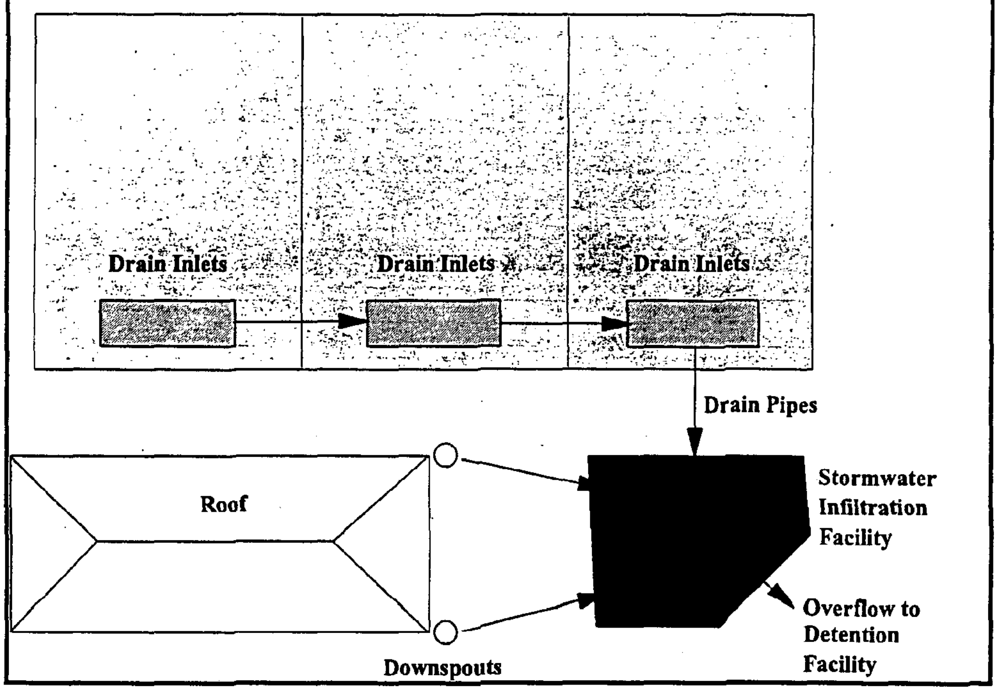
Utilize Terraces, Contoured Landscapes, Runoff Spreaders, Diversions and Grassed or Rock-Lined Waterways

These measures increase the time of concentration by increasing length of overland flow, and thus lowering the flood peak. They will provide the additional benefit of reducing total runoff by infiltration if the site has well-drained soils. Runoff spreaders spread runoff or direct it into a system of terraces. Terraces are more suitable for reducing erosion from agricultural and non-urban areas and conserving soil moisture. They reduce effective slope length and runoff concentration. About 90% of the soil that is moved is deposited in the terrace channels. In contouring, crop rows follow field contours to prevent erosion and runoff. It can reduce average soil loss by 50% on moderate slopes and less on steep slopes. It must be supported by terraces on long slopes. There are no soil or climatic limitations on practicing contouring, but it is not feasible on very irregular topography. Grassed waterways or swales stabilize vegetation on drainage channels. For velocities of up to 8 ft/sec runoff is reduced by grass channels, if correctly graded and stabilized. Detailed design information for this category of alternatives can be obtained from the Soil Conservation Service's Engineering Field Manual for Conservation Practices.

Use of Infiltration Devices

Infiltration devices are used to reduce flood peaks by releasing all or part of the stored runoff into the ground water. The infiltrated water may appear a short distance downstream as surface water at a later time. However, the runoff hydrograph at the outlet point should be much lower and drawn out in time than that from runoff delay techniques [Aron, 1975]. An example application of infiltration storage techniques is provided in Figure VI-1.

Figure VI-1
Example Application of Roof and Parking Lot Infiltration Facility



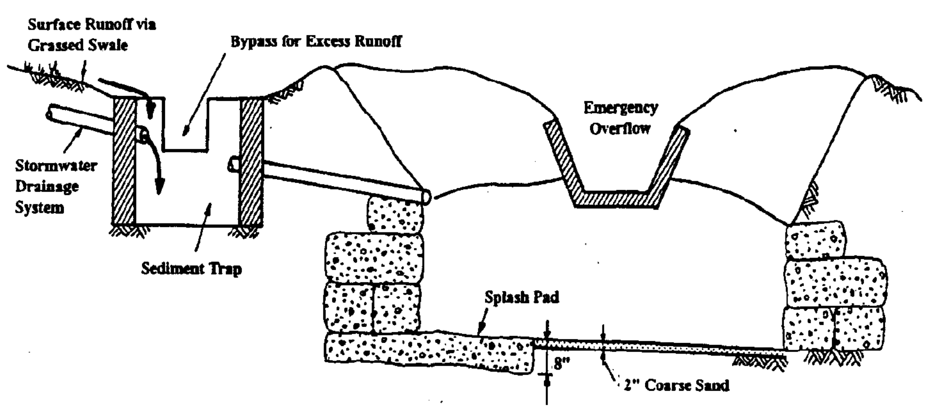
Soils comprised of sands and/or silty sands have high infiltration capacities, and therefore are well suited for infiltration storage. Soils comprised of fine silts and clays have low infiltration capacities and therefore, are not suitable for constructing infiltration devices over them. Deep soil sampling should be performed to assess the feasibility of water loading the various geological strata for purposes of stormwater disposal. Percolation tests, pumping tests, and soil sampling should provide useful data about the depth, size, and location where subsurface storage is practical. In the Lake Erie Area Watershed, a number of the soils have properties which can limit the applicability of infiltration storage. Therefore, this alternative should be used with caution. If this method is proposed as the primary means to reduce runoff for large development sites or for sites located in landslide-prone soil locations, a soil engineer's report should be obtained. Moreover, infiltration systems should not be used where there is a reasonable probability the runoff may be contaminated (e.g. industrial sites, commercial parking lots, etc.).

The following techniques for stormwater control are based on the principle of encouraging infiltration to ground water.

Seepage or Recharge Basins

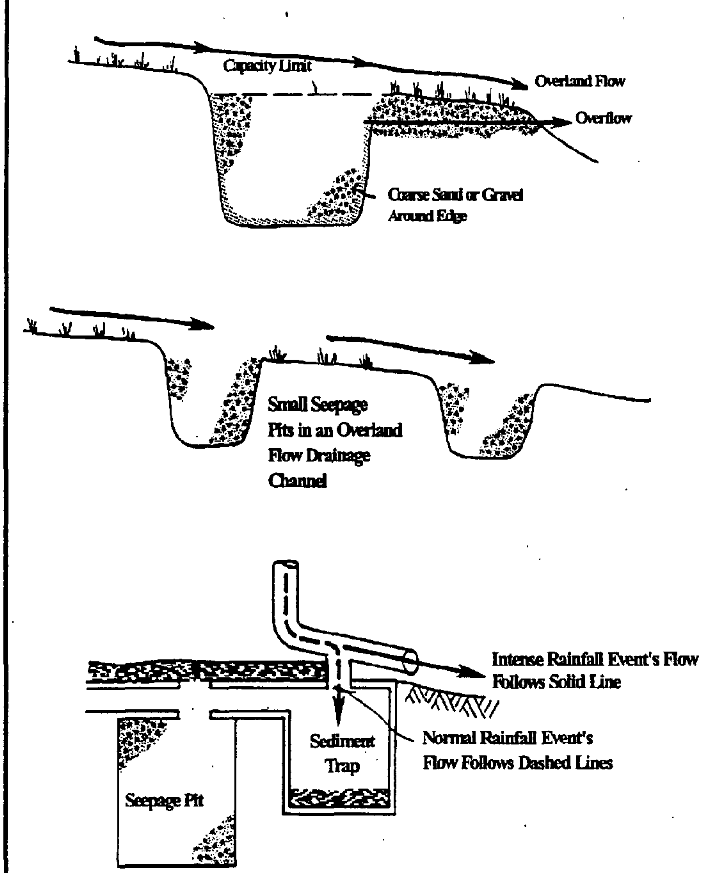
Figure VI-2 shows a typical design of a seepage or recharge basin. In this method, runoff is collected in various storm drainage systems and then passed into large excavations called seepage or recharge basins designed to allow a large percentage of annual rainfall to recharge an underlying aquifer. In addition to reducing runoff volumes, this method offers to put the stormwater to beneficial use by allowing a large percentage of runoff to recharge an aquifer.

Figure VI-2
Seepage or Recharge Basin



Generally, the infiltration basins must be located in aquifer recharge areas, but they may be used whenever the water table is more than 48" below the ground surface. If they are used as the only means of stormwater control, their size must be sufficient to store the area's maximum design rainfall from all paved areas. However, seepage or recharge basins are economically more feasible if designed to recharge a limited amount of the runoff that is produced by rainfall events and to overflow relatively early during intense rainfall events. Control of this overflow may require the use of additional stormwater management facilities. As indicted above, when seepage basins are used there is a need to consider the impacts of the type and quality of runoff being infiltrated; e.g., water quality impacts on ground water, and possibility of the pit being sealed by the salts in the water. Seepage basins should not be used where there is a significant potential for pollution of the ground water. In order to maintain good infiltration rates, the bottom of the basin should be kept silt free by using a sediment trap. In addition, an emergency overflow structure is required to bypass excess runoff.

Figure VI-3
Seepage Pits



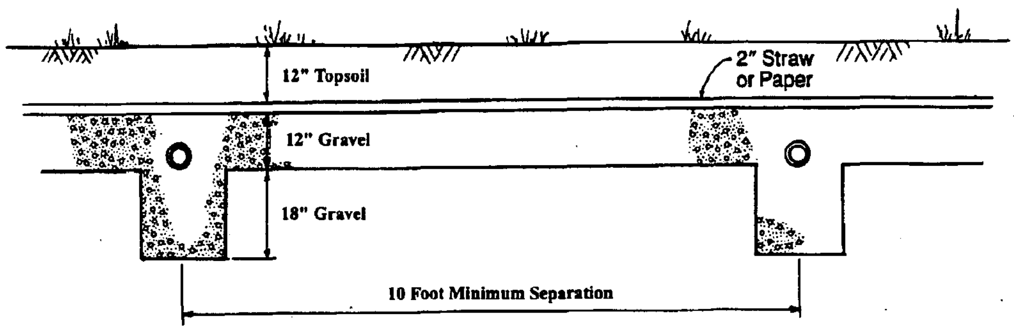
Seepage Pits or Dry Wells

Seepage pits are small excavations designed to overflow during intense storms, but reduce flood peaks by encouraging infiltration to ground water. They can be effectively used at the sites where soil permeability is over 0.15 ft/day and water table is more than 48" below the bottom of the pit. There are two important design considerations associated with seepage pits: (1) the minimum size (which depends on porosity of the soil porosity of the soil and design storm) should be sufficient to maintain predevelopment infiltration rate; (2) side area should be at least two times larger than the bottom area. Figure VI-3 shows three seepage pit designs each with an alternative overflow mechanism.

Seepage Beds or Ditches

Seepage beds dispose of runoff by infiltration it into the soil through a system of perforated pipes laid in ditches. The runoff should be allowed to pass through a sediment trap as shown in Figure 1, with a bypass structure to drain runoff from extreme rainfall events. They are not suitable for sites with water tables less than 48" deep and extremely low permeability. A typical design of a seepage bed is shown in Figure VI-4.

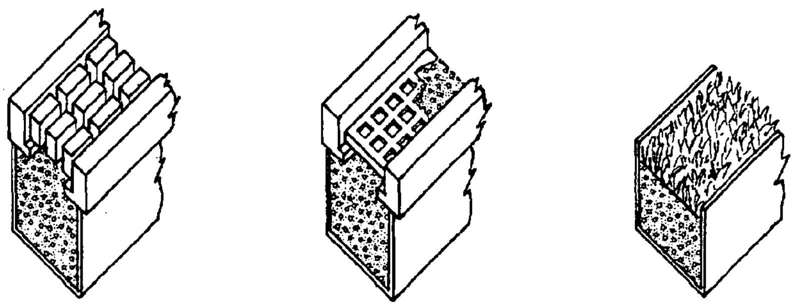
Figure Vi-4
Seepage Bed



Dutch Drains

Dutch drains are employed in residential developments. They are simply ditches either filled entirely with gravel or covered with top soil and seeded. Very wide drains are usually covered with brick lattice or porous block as shown in Figure VI-5. The drains may either be located directly under the roof eaves along the length of a building, or runoff can be routed from downspouts to the dutch drain.

Table VI-5
Dutch Drains



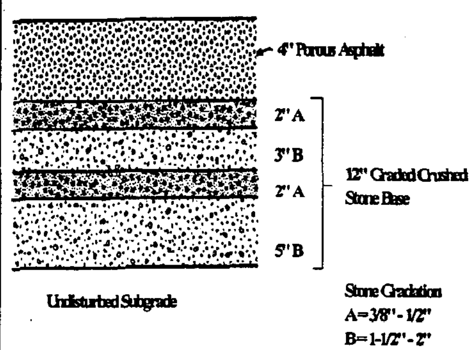
Brick Lattice | Porous Block | Grass

If dutch drains are the only means of stormwater disposal in a development, they should be able to drain area's design rainfall alone, and therefore their size will be quite large. More often two to four feet drains are combined with other control alternatives for partial stormwater management using dutch drains.

Porous Pavement

Porous pavement is a special asphalt mixture designed to pass water at a high rate to a specially prepared subbase. The special subbase is thicker than a normal gravel subbase and is composed of coarse graded stone supplying large void spaces to store infiltrated runoff. Figure VI-6

Table 6
Typical Cross Section of
Porous Pavement



runoff. Figure VI-6 shows a typical porous pavement cross-section. The base aggregate is designed to have about 40% voids ratio.

Regardless of design traffic number (DTN), a minimum surface thickness of 4" should be provided. Also, the combined surface and base thickness should not be less than anticipated frost penetration. Porous pavements have shown very positive results in regard to permeabilities, wear resistance and freezing - thawing effects. However, the main problem with porous pavements is that of pore clogging by muddy tires.

PEAK DISCHARGE CONTROL DEVICES

Peak discharge control devices are those which control peak discharges rates by either lengthening the runoff path of the storm water or storing it and releasing it at a controlled rate. The runoff delay may vary between 15 to 30 minutes for very small areas to several hours for drainage basins of larger extent. A common goal of delay devices is, however, the disposal of all stored water before a second storm might hit. The stored water must be allowed to release at a flow rate that is designed not to cause harm.

Delay of runoff is accomplished by two basic principles of detention and retention. Detention is defined as detaining a large portion of the runoff from a storm, for a time period approximately equal to the natural runoff duration. Retention, on the other hand, is defined as holding of runoff for some time period longer than the natural runoff period. There are following alternatives available based on the principle of runoff delay.

There are a number of on-site locations for temporary storage of precipitation and runoff are generally considered:

1. Storage in ponds and lakes
2. Rooftop storage
3. Underground storage

4. Parking lot storage
5. Blue-green storage
6. Multiple use storage areas

In planning on-site storage methods, one should consider existing physical, social and economic limitations of the area. What may be a good solution at one site, may be inappropriate at another.

Detention and Retention Basins

Detention and retention basins take a variety of forms. Some are wet (filled with water all of the time) and some are dry (filled with water only during storms).

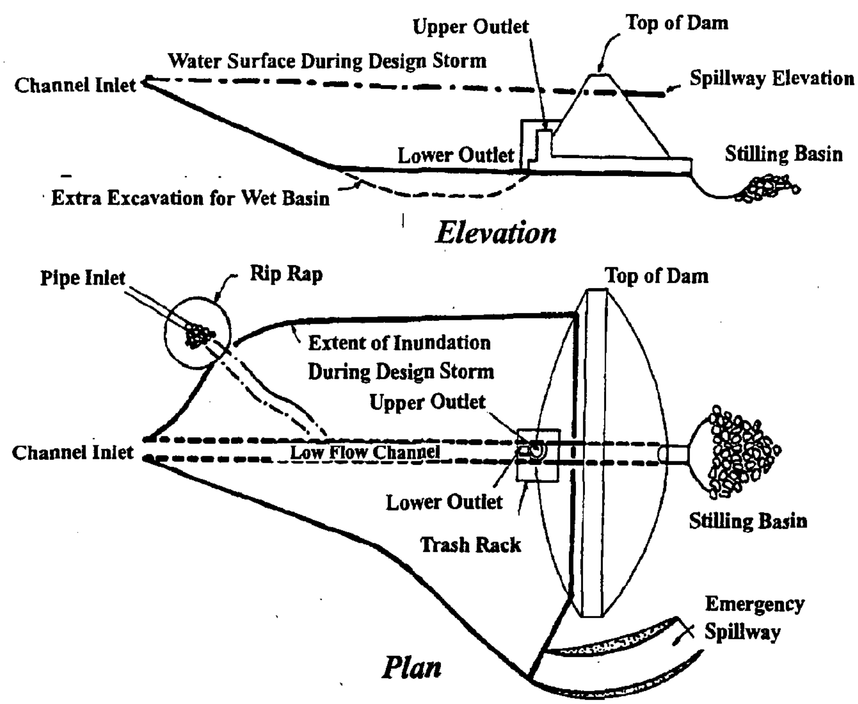
Some are designed as a continuation of a stream or river (on-stream basins) while others are separate from the river (off-site basins). Off-stream basins are usually connected to the water course by pipes or swales.

Dry Ponds

As the name implies, dry ponds are designed to be normally dry with the ability store a portion of the stormwater during a storm event and then release the stored volume slowly and safely. Typically they are used in areas where runoff volume has been increased and it is desirable to reduce the runoff rate.

Retention basins are used when extreme limits on downstream flow rate or velocity are required. The outflow rate will be relatively low and extended over a longer period of time as compared to the outflow period of detention basin. This requires large amounts of storage for detaining stormwater for periods greater than 24 hours. Figure VI-7 shows a typical detention basin design. One detention basin can be designed to control the stormwater from 2, 10, 25 and 100-year design storm events, by constructing multi-stage outlet structures. The outlet flow discharge rate from the basin will depend on the return period of the design storm.

Table VI-7
Typical Detention Basin Design



Rooftop Retention

Rooftop retention utilizes the built-in structural capabilities of rooftops to store a certain amount of rainfall that falls on them. In many cases, existing roof structures require little modification to function as retention structures. On flat rooftops, drains must be designed with proper outlet capacities to control release rates to the design level. Overflow mechanisms should be provided to preclude danger from overloading.

Special considerations of roof water tightness may be necessary when water is to be detained for longer time periods or where frequent freezing and thawing are prevalent. Figure VI-8 illustrates several types of rooftop retention devices. On sloping roofs, the retention can be achieved by providing findams. Findams are actually about 4" high gravel ridges at 15 to 30 ft spacing as shown in Figure VI-9. Individual wedge-shaped ponds would build up behind these "minidikes". Through laboratory studies it was found that a series of five dikes of 1/4 inch gravel placed on roofs of 1% slope will cut the peak runoff runoff rate by 50% and extend the runoff time by about 30 minutes [Aron, 1975]. Finer gravel would naturally delay the runoff further. The effectiveness of the rooftop storage is a function of the actual area affected by such storage. It is most effective when used as an integral part of a larger stormwater runoff control plan. Detailed structural analyses of the structure should be completed to assure that the added roof load represented by stored water can be safely supported. Moreover, additional maintenance should be anticipated on roofs subject to leaf accumulation.

Figure VI-8
Examples of Rooftop Detention Devices

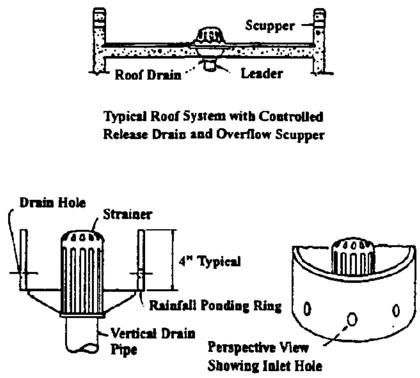
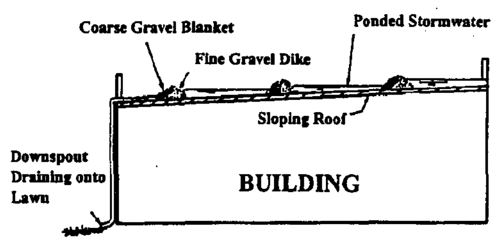


Table VI-9
Roof Ponding With Gravel Dikes



Wet Ponds

Permanent or wet ponds are detention/retention structures filled with water all the time with adequate detention capacity to store the design floods above normal ponds level. Overflow spillways must be provided to bypass or discharge flows into floodways on the peripheries of the ponds so that safe water-storage elevations are not exceeded nor banks breached.

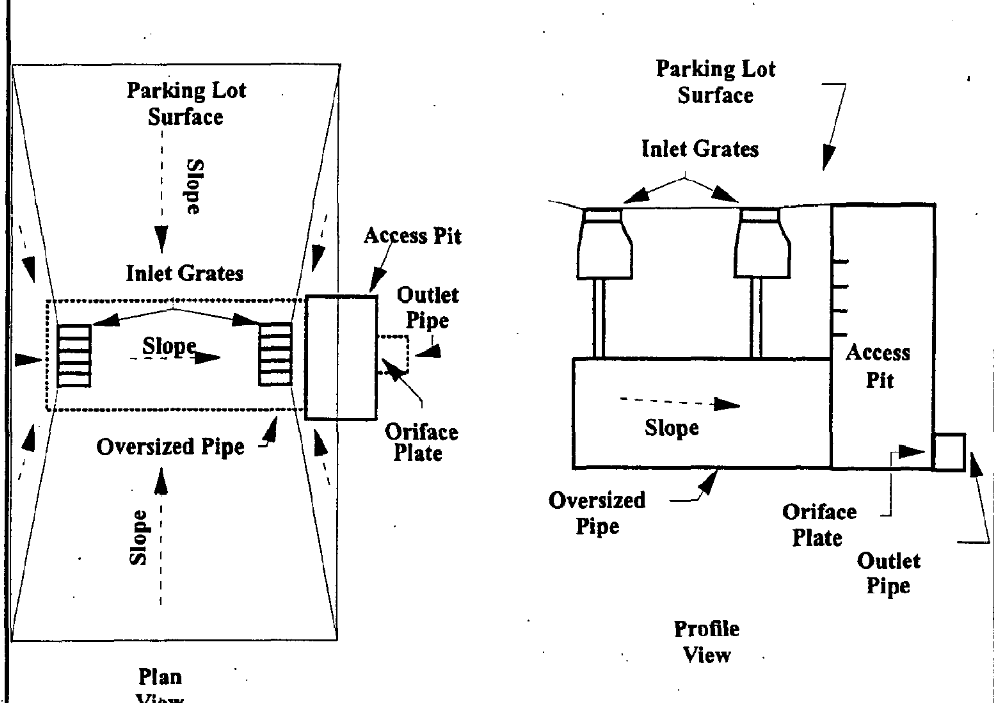
For extremely large ponds, adequate design precautions should be taken to minimize possible shoreline erosion due to ice, wind and wave action. Sediment accumulation and water pollution due to roadside accumulations of salts, copper, and asbestos from brake linings, grease, oil, and heavy metals, are the disadvantages associated with wet ponds. Such deleterious material should be screened out from the drainage system by interception and disposition before it reaches stormwater storage ponds. In some locations municipal, state or federal safety standards regarding the depth and volume of water will have to be met. These ponds are unquestionably more aesthetically appealing than a typical dry detention basin. In addition, they can be designed to provide some recreational benefits. North Park Lake is an example of a permanent pool. Figure 10 shows some suitable locations in a site plan for a residential development [Becker et al., 1973].

The main difficulty with wet ponds lies in the frequent unavailability of land. Dry ponds can be made rather inconspicuous as an integral part of the landscaping or as lawn areas for office buildings. For example, depressed front lawn areas can be designed to detain runoff from intense storms and to serve as building's green space in dry season. The outlet pipes allow the ponds to drain in 12 to 24 hours, and a certain amount of water undoubtedly filters into the ground [Aron, 1975] - thus drying the areas and returning them to a suitable condition for dry weather uses.

Underground Detention/Retention Tanks

This alternative involves the construction of underground holding tanks or large sized pipes as a means of providing controlled runoff from the site. In areas where land is expensive or surface topography is not suitable, these tanks can serve the same function as basins, while conserving land area. Outflow control devices may consist of small gravity pipes, or weirs. In some applications pumping may be required to discharge the stored runoff. This method can be quite expensive because of high material construction costs and possible pumping requirements; however, they may be appropriate in situations where land area is at a premium. An example general design of an underground stormwater detention facility is illustrated in Figure VI-10.

Figure VI-10
Underground Detention Facility



Parking Lot Detention

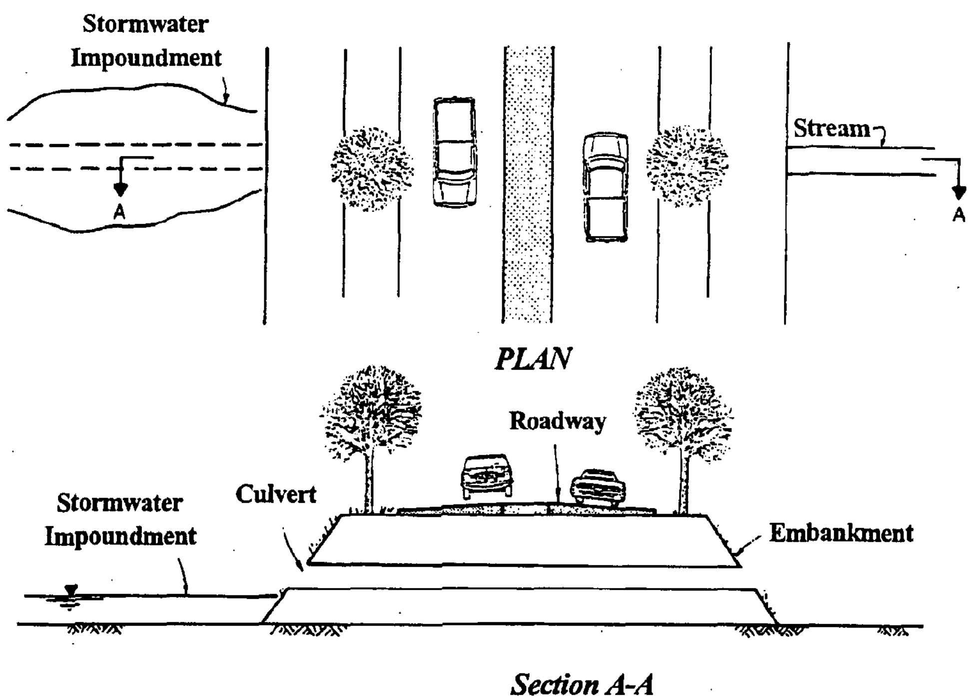
Parking lots cover a major portion of commercial developments and are, therefore, large contributors of stormwater runoff. Stormwater runoff can be detained on parking lot sites by shallow basins or swales. If properly designed, this measure can be quite effective. Initial construction costs implementing these measures are only a small percentage above the construction cost of conventional parking lots. Arrangements of areas in a parking lot to accept ponding should be planned so that pedestrians are inconvenienced as little as possible. A 7" design depth is not unreasonable for parking locations in the remote areas of lots [APWA, 1981]. The facility should be designed to drain completely and avoid formation of ice.

Design considerations should recognize the possible use of porous asphalt, provided the subgrade has an adequate infiltration capability. Expansive and/or collapsing type soils may preclude this solution. An alternative to impervious paving of parking areas is the substitution of grassy strips. The ground surface of the planting strip is depressed and driving lanes are graded to direct the storm runoff into the depressions. The strips should be filled with pervious soil to allow a maximum of infiltration, and planted with a Fescue-type grass which is both resistant to occasional swamping and dry soil conditions. The strips should be oriented perpendicular to the parking lot slope and surrounded by broken curbs to protect them from being overrun by cars.

Blue-Green Storage

Incorporation of stormwater storage in urban drainage ways traversing roadways is a version of detention ponding that has been identified as the blue green concept. Topographical characteristics of many land areas adjacent to roadway embankments make them very much adaptable for use as detention facilities. This can be achieved by designing the culverts to pond where appropriate, as shown in Figure VI-11. Many drainage structures can be designed to operate in this fashion. Roadway embankments at control points should be stabilized and protected to minimize erosion effects of retained water.

Figure VI-11
Road Embankment Stormwater Detention



Detention within Pedestrian Plazas and Malls

On-site detention in heavily congested areas can be incorporated effectively in the design of pedestrian plazas, malls, and other similar type developments. The ponding requirement can be accomplished at selected locations with very shallow depths (1 to 3 in) to avoid public inconvenience. Frequent maintenance and suitable discharge control devices designed to satisfy the architectural objectives of the land development are necessary in developments of this type.

Multiple Use Impoundment Areas

These areas utilize sites having primary functions other than runoff control. In new developments, such multiple use should be incorporated into the primary design. For example, open space and grassed areas provided in the land development to enhance the aesthetic appeal can also be used as stormwater detention facilities. This can be accomplished by providing stormwater release controls such as weirs, orifices, small diameter pipes and gates etc.

A hard-surface basketball or tennis court can be designed to drain adjacent grassed or paved areas. The stormwater would collect in grass swales around the edge of the court, seep through a gravel drain to retain the sediment load, and discharge onto a porous asphalt surface. Some type of emergency drain should be provided. Positive drainage toward the control devices is essential to avoid the swampy conditions, weed growth and increased maintenance costs. For optimum operation of control structures, it is also essential to screen out the floating debris from the inlet stormwater.

RELATIVE ADVANTAGES AND DISADVANTAGES

Table VI-1 gives a brief summary of principal urban runoff abatement practices and their associated relative advantages and disadvantages. As was expressed previously, the runoff volume reduction measures which simultaneously reduce runoff peaks offer significant advantages from the perspective of both local and watershed wide effects. However, since there are limitations inherent in the volume reduction techniques, it is likely that an overall stormwater control plan will include a combination of applicable volume reduction features and peak discharge control features (i.e. detention and/or retention facilities).

Selection of the best combination of techniques to be used in a particular instance should be made by the developer in consultation, or at least with the concurrence, of the municipal reviewer.

TABLE VI-1

ADVANTAGES AND DISADVANTAGES OF ON-SITE CONTROL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
REDUCTION OF RUNOFF / INFILTRATION STORAGE		
Dutch Drains	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rate. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down-slope stormwater control facilities.	- Looses efficiency if intensive storms follow in rapid succession. - Subject to clogging by sediment. - Limited to application for small sources of run-off only, i.e., roof drains, small parking lots, tennis courts. - Maintenance is difficult when the facility becomes clogged. - Limited application in poor infiltration soils.
Porous Pavement	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down-slope stormwater control facilities. - Less costly than conven-tional pavements for most applications. - Safety features - superior skid resistance and visi-bility of pavement markings. - Provides pavement drainage without contouring.	- More prone to water stripping than conven-tional mixtures. - Subject to clogging by sediment. - Water freezing within the pores takes longer to thaw and limits infiltration. - Motor oil drippings and gasoline spillage may pollute groundwater. - Limited application in poor infiltration soils. - recent studies suggest that porous pavement's advantage will reduce with time.

TABLE VI-1

ADVANTAGES AND DISADVANTAGES OF ON-SITE CONTROL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
	- Prevents puddling on the surface.	
Seepage/Recharge Basins	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Construction borrow pits often can be converted to a large seepage basin to serve multiple areas.	- Must be fenced and regularly maintained. - If porosity is greatly reduced, it may be necessary to bore seepage holes or pits in the base. - No filtering supplied by the topsoil. - Usefulness limited in poor infiltrations soils.
Seepage Pits	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances the groundwater supply. - Provides additional water for vegetation in the area. - Reduces the size of down-slope stormwater control facilities.	- Looses efficiency if intensive storms follow in rapid succession. - Subject to clogging by sediment. - Maintenance is difficult when the facility becomes clogged. - Limited utility in poor soils.
Seepage Beds/Ditches	- Reduces the total volume of runoff. - Reduces the peak runoff discharge rates. - Enhances groundwater supply. - Reduces the size of down-slope stormwater control facilities. - Distributes stormwater over a larger area than other infiltration	- More expensive than other infiltration techniques. - Replacement of entire system if clogging by sediment should occur. - Maintenance of sediment traps must be frequent and consequently more expensive.

TABLE VI-1

ADVANTAGES AND DISADVANTAGES OF ON-SITE CONTROL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
	techniques. - May be placed under paved areas if the bearing capacity of the paved area is not affected. - Safer than seepage or recharge basins.	
Terraces, Diversions, Runoff Spreaders, Grassed Waterways, and Contoured Land-scapes	- Increases the overland flow time, increasing the time of concentration and allowing for increased infiltration. - Vegetative swales are less expensive than curb and gutter systems.	- On poorly drained soils, these techniques may leave ground waterlogged for extended periods after storms. - vegetative channels may require more maintenance than curb and gutter systems. - Roadside swales become less feasible as the number of driveway entrances requiring culverts increase.
DELAY OF RUNOFF		
Rooftop Retention	- No additional land requirements. - Not unsightly or a safety hazard. - May be adapted to existing structures.	- Leaks may cause damage to buildings and contents. - Stored runoff will greatly increase the load imposed on structural support. This increased construc-tion expense may be greater than the savings resulting from reducing the size of downslope stormwater management facilities.

TABLE VI-1

ADVANTAGES AND DISADVANTAGES OF ON-SITE CONTROL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
Parking Lot Detention	- Adaptable to both existing and proposed parking facilities. - Parking lot storage is usually easy to incorporate into parking lot design and construction.	- May cause an inconvenience to people. - Ponding areas are prone to icing, requiring more frequent maintenance.
Multiple Use	- Serves more than one purpose. Employing areas of grass, a certain amount of stormwater will infiltrate and improve the quantity of water recharged by natural filtering processes. - If porous pavement is used on basketball or tennis courts, additional infiltration will be provided.	- Difficult to maintain the porosity of multi-use areas.
Detention/Retention Basins	- Offers design flexibility for adapting to a variety of uses. - Construction of ponds is relatively simple. - May allow significant reduction in the size of downslope stormwater management facilities. - May have some recreational and aesthetic benefits if runoff is not carrying heavy sediment loads.	- Facilities that empty out completely can have an unsightly nature and be a detriment to the developments. - Difficulty in establishing a regular maintenance program. - In a residential development, it may be difficult to determine whose responsibility it is to pay for the maintenance program. - Consumes land area which could be used for other purposes.

TABLE VI-1

ADVANTAGES AND DISADVANTAGES OF ON-SITE CONTROL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
Permanent Ponds	- Will provide both a reduction in peak runoff rates and a source of recreation in any residential area. - Only minor modifications may be required to adapt an existing pond for use as a permanent stormwater management facility. - Wildlife habitat and wetlands may be preserved	- Stormwater runoff having a high sediment or pollutant load should not be controlled in existing ponds because of its adverse impact on the natural conditions.
Underground Retention/ Detention Tanks	- Minimal interference with traffic or people. - Can be used in existing as well as newly developed areas. - Potential for using storm-water for nonpotable uses.	- Subsurface excavation could be extremely expen-sive depending upon the type and amount of rock encountered. - Access for maintenance may be difficult if proper design features are not provided.

STORMWATER QUALITY BEST MANAGEMENT PRACTICES

The volumes and rates of stormwater runoff from land developments are a major concern in stormwater management. However, they are not the only consideration. The impacts of stormwater runoff upon water quality are becoming of increasing concern. The predominant categories of pollutants that have been identified in stormwater runoff from developed areas are listed below.

- sediments
- nutrients
- pathogens
- organic enrichment
- toxic pollutants
- salts

There are a number of methods through which the negative effects of stormwater runoff pollution can be minimized. These methods are generally referred to as *best management practices for stormwater quality control (BMPs)*. These best management practices are generally low cost, relatively low technology methods of reducing the pollutant content of stormwater runoff. The following sections describe the most commonly employed stormwater quality BMPs. As is indicated by the following information, most of the stormwater quality BMPs also are effective in controlling the volumes and rates of stormwater runoff produced by new land developments and were presented previously in the context of stormwater flow control. It is fortunate that the most effective stormwater management controls have the dual benefits of reducing stormwater quantities and improving runoff quality.

Vegetative Best Management Practices

All of the following practices rely on various forms of vegetation to enhance the pollutant removal, habitat value, or appearance of a development site. Although in practice each technique, by itself, is usually not capable of entirely controlling increased runoff and pollutant export for a development site, they can improve the performance and amenity value of other BMPs. These practices, therefore, should be considered as an integral part of every development site plan.

Limiting the Amount of Land Disturbed (Urban Forestry)

Limiting the amount of land disturbed and/or replanting vegetation following completion of construction can reduce pollutants in stormwater runoff in several ways: 1) through plant uptake and storage, 2) by reducing the volume of stormwater runoff and the associated pollutants, 3) through filtering, and 4) by preventing soil erosion. With careful landscape design, as much as 50% of a residential lot can be converted into an attractive natural setting of trees, shrubs, and ground covers. The extent to which pervious, vegetated areas can be preserved and/or created will have a direct effect upon the volume of stormwater runoff and the quantities of associated pollutants that will be produced. Moreover, the cost of maintaining the vegetated areas is relatively low and the aesthetic value to the overall development can be quite high.

Grassed Swales

Grassed swales are typically applied in residential developments and highway medians as an alternative to curb and gutter drainage systems. Figure VI-12 presents an example of a grassed swale. Grassed swales remove pollutants through the filtering action of the grass, deposition in low velocity areas, and by infiltration into the subsoil. These mechanisms are most effective in removing particulate effective in removing particulate pollutants and have a negligible effect on soluble pollutants. Swales are generally less expensive to construction than curb and gutter systems and maintenance is relatively low cost, generally consisting of normal lawn maintenance activities such as mowing and watering as needed.

Figure VI-12
Illustration of Grassed Lined Swale

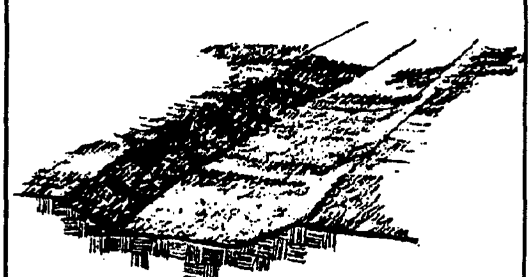


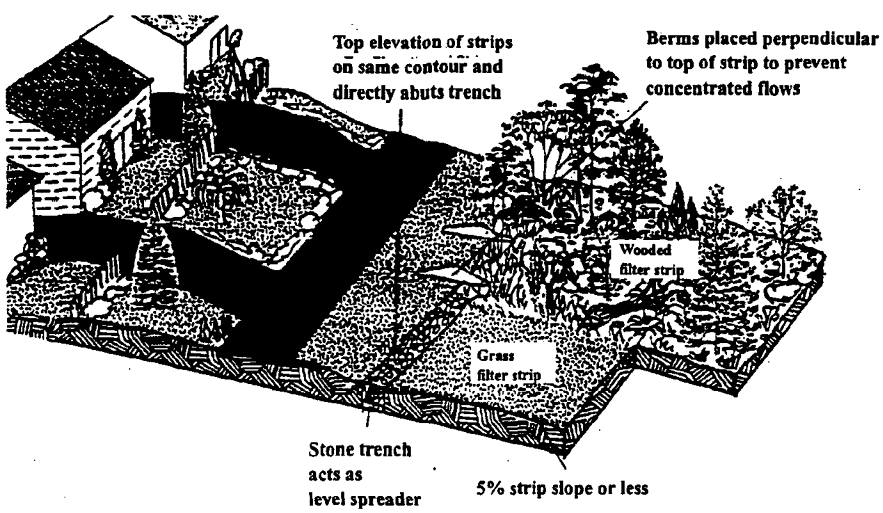
Figure VI-13
Illustration of Rock Lined Channel

A variation to grassed swales is a rock lined waterway (Figure VI-13). A rock lined waterway consists of a channel lined with rock. These channels are generally less effective that grassed swales in the removal of pollutants due to a reduced filtering through the grass. However, some suspended pollutants are removed through deposition in low velocity areas.

Filter Strips

Filter strips are similar to grassed swales in many respects. However, they differ in that they are designed to only accept overland sheet flow and are not intended to serve a dual purpose as a conveyance facility. In practice, runoff from an adjacent impervious area is evenly distributed across the filter strips. To perform properly, a filter strip must be: 1) equipped with some sort of level spreading device; 2) densely vegetated with a mix of erosion resistant plant species that effectively bind the soil; 3) graded to a uniform, even, and relatively low slope, and 4) be at least as long as the contributing runoff area. Filter strips are especially effective when constructed as a buffer between the development activities and adjacent streams, curbs, and swales. They can also be used to protect surface infiltration trenches from clogging by sediment. An example of an application of filter strips is presented in Figure VI-14.

Figure VI-14
Example Application of Vegetated Filter Strips

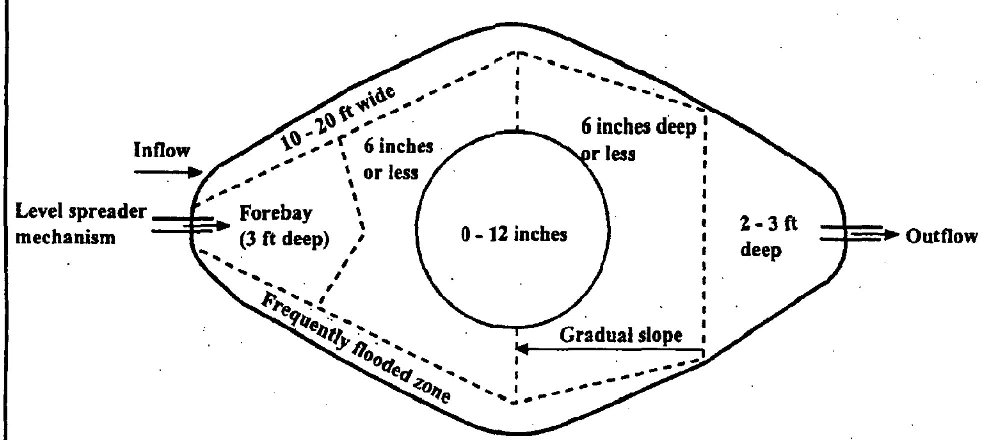


The pollutant removal mechanisms in filter strips are similar to those presented previously for grassed swales. As is the case with grassed swales, filter strips are particularly effective in removing particulate pollutants such as sediment, organic material, and many trace metals. Filter strips are relatively inexpensive to establish and cost almost nothing if preserved during site development. A creatively landscaped filter strip can become a valuable community amenity, providing wildlife habitat, screening, and stream protection. The open space created by the filter strips can also be applied toward meeting established development density limitations that may be contained in local ordinances.

Constructed Wetlands

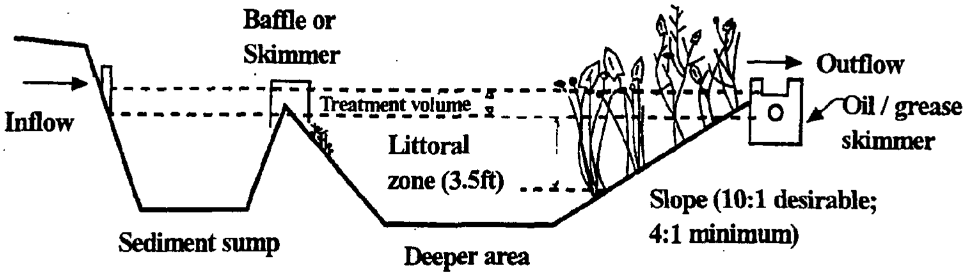
There are two prevalent types of constructed wetlands in use: 1) shallow constructed wetlands (Figure VI-15) and 2) wet detention systems (Figure VI-16). Constructed wetland systems perform a series of pollutant mechanisms, including sedimentation, filtration, adsorption, microbial decomposition, and vegetative uptake to remove sediment, nutrients, oil and grease, bacteria, and metals. While constructed wetlands can be very effective in the removal of the broad range of pollutants encountered in stormwater runoff, it is important that they be properly designed, sited, and maintained. The critical design consideration is the

Figure VI-15
Schematic of a Shallow Constructed Wetland



maximization of the detention time in the wetland through proper sizing and configuration to prevent short circuiting.

Figure VI-16
Example Wet Detention Wetland System



Siting of wetlands can be difficult due to the importance of soil properties (chiefly permeability) to performance, size requirements, and concerns relative to potential nuisance insect breeding. In addition, created wetlands become a resource area that will subsequently be protected by federal and state laws.

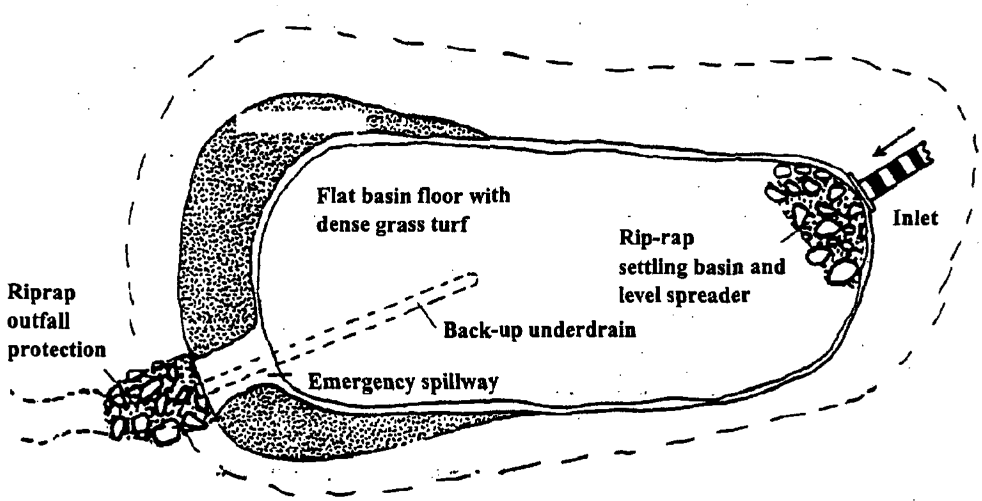
Infiltration Facilities

Infiltration facilities permanently capture runoff so that it soaks to the ground water. As was presented previously, to the extent of their capacity to handle the volumes of stormwater runoff produced, they are very effective in controlling stormwater runoff flows. They also can be very effective in removing pollutants. Pollutant removal in these BMPs occurs primarily through infiltration, which eliminates the runoff volume or lowers it by the capacity of the facility. Currently, the three types of facilities commonly employed to remove pollutants from stormwater runoff through infiltration are: 1) infiltration basins; 2) infiltration trenches / dry wells; and 3) porous pavements (grassed swales, which also promote infiltration were discussed previously under vegetative practices).

Infiltration Basins

Infiltration basins are similar to dry ponds, except that infiltration basins have only an emergency spillway and no standard outlet structure (see Figure VI-17). All flow entering an infiltration basin (up to the capacity of the basin) is retained and allowed to infiltrate into the soil. Infiltration basins provide pollutant removal through volume reduction, filtration, and settling. They are particularly effective in removing bacteria, suspended solids, insoluble nutrients, oil and grease, and floating wastes. They are less effective in removing dissolved nutrients, some toxic pollutants, and chlorides. Therefore, infiltration basins should not be used in cases where the runoff can be suspected to contain significant amounts of those pollutants.

Figure VI-17
Example Infiltration Basin Layout



Infiltration basins often have relatively large land requirements and require a suitable soil to be effective. Accumulating runoff must be able to infiltrate the soil in the bottom of the basin. Typically sand and loam, with infiltration rates greater that or equal to 0.27 inches per hour are the preferred soils. Soils with percolation rates meeting this criteria exist throughout the watershed. However, high or seasonally high water tables predominate throughout most of the watershed. For infiltration to occur, ground water levels should be located at least 2 to 4 feet below the bottom of the basin. Consequently, the use of infiltration basins will not be practical throughout most of the Lake Erie Area Watershed.

Infiltration Trenches / Dry Wells

Subsurface infiltration practices, such as infiltration trenches or dry wells force runoff into the soil to recharge ground water and remove pollutants. Filtration is the primary pollutant removal mechanism active in these facilities. They effectively remove suspended sediments, floating materials, and bacteria. They are less effective at removing dissolved materials.

The soil infiltration rate and structure size are the most important considerations in the design of infiltration structures. The soils underlying the structures must be tested to determine their infiltration capacity and the ground water level. The soil must neither be too impermeable to runoff nor to rapidly permeable. Moreover, a distance of at least 2 feet should be maintained between the bottom of the infiltration structure and the mean high ground water elevation. Due to the nature of prevailing conditions in the area, siting of infiltration facilities must be made carefully throughout the Lake Erie Area Watershed.

Porous Pavement

By allowing stormwater to infiltrate into the soil, porous pavements can reduce runoff volume and pollutant discharge. Porous pavements can remove significant amounts of both soluble and particulate pollutants. Porous pavement is primarily designed to remove pollutants deposited from the atmosphere, as coarse solids can clog the pavement pores. As a result, porous pavements are generally designed into parking areas that receive light traffic.

As is the case with all of the infiltration systems, the effectiveness of porous pavements for pollutant removal is highly dependent upon soil characteristics and ground water levels. The soils under the pavement system must produce adequate infiltration and ground water levels should be 2 to 4 feet below the bottom of the paving and subbase system. Proper maintenance of porous pavements is important and can be extensive. The pavement must be kept free of coarse particles that can clog the pavement and prevent runoff from infiltrating. The pavement must, therefore, be regularly inspected and cleaned with a vacuum sweeper and high pressure jet.

Detention Facilities

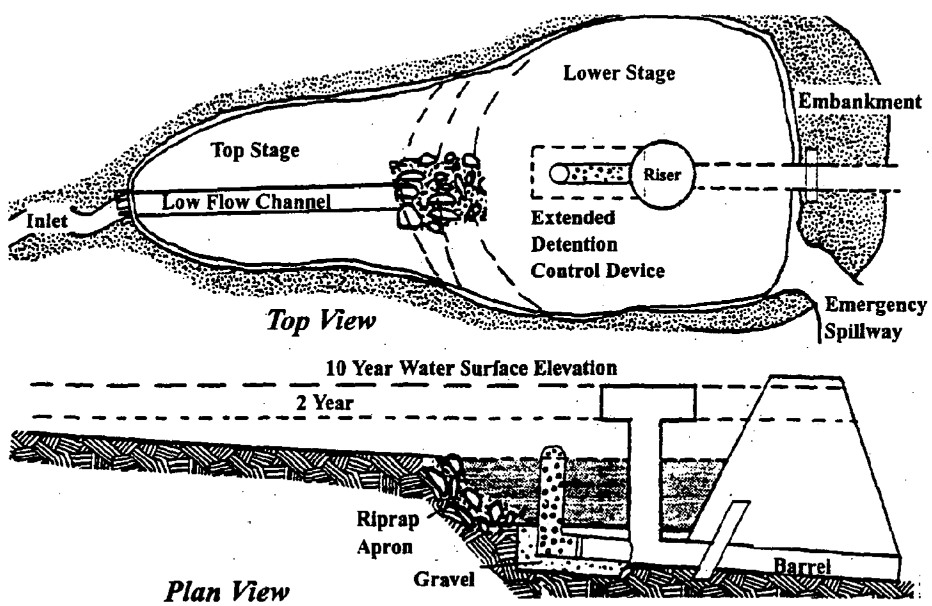
One of the most common structural methods of controlling runoff is through the construction of ponds to collect runoff, detain it, and release it to receiving waters at a controlled rate. Pollution reduction during the temporary period of runoff storage results primarily from the settling of solids. Detention facilities, therefore, are most effective at reducing the concentrations of solids and the pollutants that adhere to solids, and less effective at removing dissolved pollutants.

The three types of detention facilities commonly used to remove pollutants from stormwater runoff are extended detention dry ponds, wet ponds, and constructed wetlands. The first two types of facilities are discussed below. Constructed wetlands were introduced previously under the topic of vegetative methods.

Extended Detention Dry Ponds

As was discussed previously in regard to flow control devices, dry ponds are frequently used to control peak discharges by temporarily detaining runoff. They are designed to completely drain at the conclusion each rainstorm event. When designed to achieve pollutant load reductions, the design of the ponds are modified to achieve longer detention times than are necessary solely to adequately control peak discharges. Generally, the ponds are designed to retain a specified runoff volume for a period of time sufficient to achieve the desired pollutant removal. This requires sufficient storage volume and an outlet flow control devices to accomplish the desired flow detention. Dry ponds should also include a low flow channel designed to reduce erosion; vegetation on the bottom of the pond to promote filtering, sedimentation, and uptake of pollutants. In addition, dry pond designs frequently include upstream structures to remove coarse sediments and reduce sedimentation and clogging of the outlet. An example of a layout of an extended detention pond is illustrate in Figure VI-18.

Figure VI-18
Schematic of a Dry Extended Detention Pond

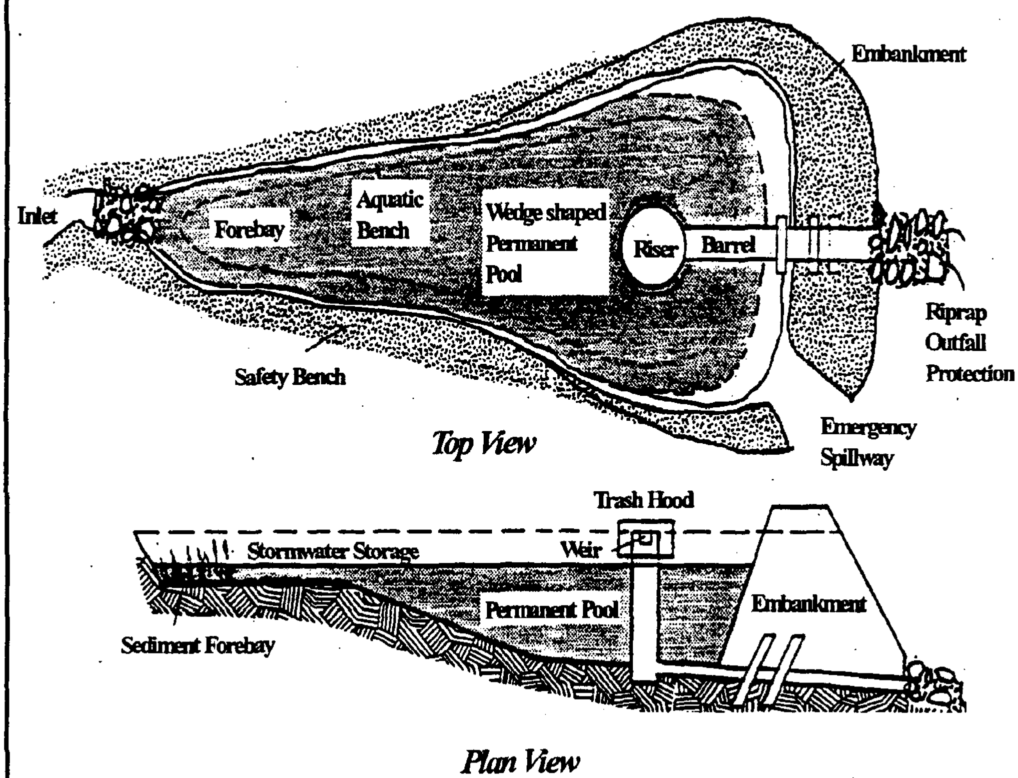


Maintenance of water quality dry ponds is important. Regular mowing, inspection, erosion control, and debris and litter removal are necessary to prevent excessive sediment buildup and vegetative overgrowth. Also, periodic nuisance and pest control could be required. The primary constraints to siting dry ponds are land requirements, topography, and depth to bedrock.

Wet Ponds

The design of wet ponds is similar to that of dry ponds. In wet ponds, however, stormwater runoff is directed into a constructed pond or enhanced natural pond, in which a permanent pool of water is maintained. Once the capacity of a wet pond is exceeded, collected runoff is discharged through an outlet structure or emergency spillway. An example of a wet pond system is presented in Figure VI-19.

Figure VI-19
Schematic of a Wet Pond



The primary pollutant removal mechanism in wet ponds is settling. The ponds are designed to collect stormwater runoff during rainfall and detain it until additional stormwater enters the pond and displaces it. While the runoff is detained, settling of particulates and associated pollutants takes place in the pond. Wet ponds can also remove pollutants from runoff through vegetative uptake. Wet ponds should be vegetated with native emergent aquatic plant species, which can remove dissolved pollutants such as nutrients from the runoff before it is discharged to the receiving water.

Wet ponds are typically designed with a number of different water levels. One level has a permanent poll of water. The next level periodically is inundated with water during storm. This level should be vegetated and relatively flat to promote settling and filtering of sediments and vegetative uptake of nutrients. The highest level will be inundated only during extremely heavy rainfall. This level should also be vegetated. Sizing of wet ponds is determined by requirements for storage volumes and desired detention times.

Maintenance requirement for wet ponds include periodic sediment removal (approximately once every 10 to 20 years), mowing, and litter removal. Factors affecting siting include land requirements, soil conditions (soils should not be excessively porous and ground water tables should be relatively high), and topography.

Summary of Water Quality Best Management Practices

As was indicated in the preceding discussion, there are a number of techniques that represent best management practices for reducing pollution associated with stormwater runoff. These techniques all also have application in efforts to control runoff volumes and peak rates of dicharge. Consequently, appropriately designed stormwater management facilities can improve runoff water quality while achieving the required control of stormwater discharge flows. Table IV-2 contains a comparison of the pollutant removal effectives for the range of BMPs discussed under various design approaches. As is indicated in Table VI-2, the effectiveness of the BMPs varies. It is important, however, to recognize the water quality benefits that are offered and to consider these benefits in the overall selection and design of stormwater management controls.

Table VI-2
Comparative Pollutant Removal of Stormwater BMP Designs

Best Management Practice / Design	Suspended Sediment	Total Phosphorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Effectiveness
Grassed Swale							
Design 1	0 to 20%	0 to 20%	0 to 20%	0 to 20%	0 to 20%	Insufficient Knowledge	Low
Design 2	20 to 40%	20 to 40%	20 to 40%	20 to 40%	0 to 20%	Insufficient Knowledge	Low
Filter Strip							
Design 3	20 to 40%	0 to 20%	0 to 20%	0 to 20%	20 to 40%	Insufficient Knowledge	Low
Design 4	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	Insufficient Knowledge	Moderate
Porous Pavement							
Design 5	40 to 60%	60 to 80%	40 to 60%	60 to 80%	40 to 60%	60 to 80%	Moderate
Design 6	80 to 100%	60 to 80%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Infiltration Basin							
Design 5	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	Moderate
Design 6	80 to 100%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Infiltration Trench							
Design 5	60 to 80%	40 to 60%	40 to 60%	60 to 80%	60 to 80%	60 to 80%	Moderate
Design 6	60 to 80%	40 to 60%	40 to 60%	60 to 80%	80 to 100%	60 to 80%	High
Design 7	80 to 100%	60 to 80%	60 to 80%	80 to 100%	80 to 100%	80 to 100%	High
Wet Pond							
Design 8	60 to 80%	40 to 60%	20 to 40%	20 to 40%	20 to 40%	Insufficient Knowledge	Moderate
Design 9	80 to 100%	40 to 60%	20 to 40%	20 to 40%	60 to 80%	Insufficient Knowledge	Moderate
Design 10	80 to 100%	60 to 80%	40 to 60%	40 to 60%	60 to 80%	Insufficient Knowledge	High
Extended Detention Pond							
Design 11	60 to 80%	20 to 40%	20 to 40%	20 to 40%	40 to 60%	Insufficient Knowledge	Moderate
Design 12	80 to 100%	40 to 60%	20 to 40%	40 to 60%	60 to 80%	Insufficient Knowledge	Moderate
Design 13	80 to 100%	60 to 80%	40 to 60%	40 to 60%	60 to 80%	Insufficient Knowledge	High

Key

- 0 to 20% Removal
- 20 to 40% Removal
- 40 to 60% Removal
- 60 to 80% Removal
- 80 to 100% Removal
- Insufficient Knowledge

Source: DER Special Protection Waters Implementation Handbook

Design 1: High slope swales with no check dams
Design 2: Low gradient swales with check dams
Design 3: 20 foot wide turf strip
Design 4: 100 foot wide forested strip with level spreader
Design 5: Facility exfiltrates first - flush: 0.5 inch runoff / impervious acre
Design 6: Facility exfiltrates one inch runoff volume per impervious acre
Design 7: Facility exfiltrates all runoff up to 2 year design storm
Design 8: Permanent pool equal to 0.5 inch storage per impervious acre
Design 9: Permanent pool equal to 2.5 (Vr); where Vr equals the mean storm runoff
Design 10: Permanent pool equal to 4.0 (Vr); where Vr equals the mean storm runoff
Design 11: First - flush runoff volume detained 6-12 hours
Design 12: Runoff volume produced by 1.0 inch detained for 24 hours
Design 13: As in design 12, but with shallow marsh in bottom stage

EROSION AND SEDIMENTATION CONTROL MEASURES

The ability of storm water runoff to transport material is a function of flow velocity and the erosion resistance of the material. As stormwater runoff flow rates increase, the flow velocity increases and more eroded material is transported. As the water travels down the watershed, channel gradients reduce flow velocity and sediment begins to be deposited in streams and storm sewers. This process, known as sedimentation, continues as the flow rate and flow velocity reduces. New developments further increase the sedimentation problem by removing natural vegetation and making the bare ground susceptible to erosion.

The following principles should be practiced for urban soil erosion and sedimentation control.

1. Keep disturbed areas small: Areas vulnerable to erosion should be disturbed the minimum amount possible. As much natural cover as possible should be retained and protected. The construction plan should be phased whenever possible in small units and in sequence such that only the area being developed is exposed. All other areas should have a good cover of vegetation or mulch.

2. Stabilize and Protect Disturbed Areas: Mechanical and/or structural methods and vegetative methods are available for stabilizing disturbed areas. These methods include seeding, mulching, sodding, retaining walls, terracing, use of chemical stabilizers, and others.

3. Keep Runoff Velocities Low: Removal of existing vegetative cover and the resulting increase in impermeable surface during development increase both the volume and velocity of runoff. Short slopes, low gradients and the preservation of natural vegetation cover help to keep stormwater velocities low and thus limit soil erosion.

4. Protect Disturbed Areas from Runoff: Protective measures that can be utilized to prevent water from entering and running over disturbed areas are diversions, waterways, structures etc.

5. Retain Sediment within the Site Area: Sediment can be retained by two methods: filtering runoff as it flows, and detaining sediment laden runoff for a period of time large enough to allow the soil particle settle. Sediment basins, vegetative filter strips, terraces and sediment barriers may be used to retain sediment. However one should not rely solely upon vegetation filter strips, since sediment may rapidly render such areas useless by killing the vegetation.

6. In-stream Control: After precipitation and runoff has concentrated, an outlet channel is needed for safe release of the water off the site. This outlet channel needs to be protected from erosion. A wide, shallow grassed water way can be a very good method. Channels with steeper gradients need structural protection along with, or instead of vegetative measures. Typical structural measures include: earth dams with a full flow pipe through the fill, weirs, flood gates, and check dams. In designing such facilities, it is important to consider the effects of the dam or embankment on upstream properties. The design must include safety features in the form of spillways and bypasses to prevent overtopping which can cause embankment failure.

The details on the design and implementation of practices described above and many others can be obtained from the Soil Conservation Service and the County Conservation District.

SOIL CHARACTERISTICS VERSUS STORMWATER MANAGEMENT ALTERNATIVES

It was mentioned earlier that the soil characteristics at the development site, such as soil permeability, water capacity, frost penetration etc. play an important role in the selection of stormwater management alternatives. This section gives specific soil information for the Lake Erie Area Watershed and discusses the soil characteristics and their impact on alternative stormwater management techniques.

Soil information for Erie County can be obtained from the publications, "Soil Survey of Erie County, Pennsylvania". These publications are prepared by Soil Conservation Service of U.S. Department of Agriculture. The survey has a general soil map showing in color, the soil associations in the county. A soil association is a landscape that has a distinct pattern of soils in defined proportions. The soil association map should not be used to determine the soil type, for selecting stormwater water management alternatives. The reason is that, a general soil map is intended to be a general guide in evaluating large areas such as a watershed, or in county-wide planning for community development. It is not a suitable map for selecting a site for locating a stormwater detention or retention facility. For example, this map can be used to establish a generalized idea, that Ellery and Alden Silt Loam soils constitute a major soil type in the Lake Erie Area Watershed. Also, the survey tells that these soils have seasonal high water tables ranging from 0 to 10 inches below the surface, thus having severely limited application for infiltration storage. Thus, a general rule can be established that infiltration storage alternative should not be approved in the Ellery and Alden Silt Loam soils unless the occurrence of the ground water table at shallow depths has been ruled out by on-site engineering tests.

Table VI-3 presents some relevant properties of the Lake Erie Area Watershed soils significant to the use of various stormwater management techniques. Table VI-4 indicates the suitability of the soils for some generalize construction activiities associated with stormwater management alternatives. General conclusions that can be drawn from the information contained in Tables VI-3 and VI-4 include the following.

1. Activities designed to minimize the creation of impervious surfaces will be appropriate throughout the watershed.
2. The construction and operation of dry and wet ponds will generally be feasible throughout the watershed, although consideration must be given to site specific soil conditions.
3. The use of large scale induced infiltration systems will generally be limited by soil and ground water conditions that frequently are not suitable for those techniques.

Table VI-3
Lake Erie Area Watershed
Relevant Soil Properties

Soil Name	Depth to Seasonal High Ground Water (Inches)	Depth To Bedrock (Inches)	Percolation Rate (Inches/Hour)
Allis Silt Loam	0 - 12	18	0.2 - 2.0
Beach and Riverwash	0	>48	> 8.3
Beach Sand (stabilized)	0 - 24	>120	> 6.3
Berrien Fine Sandy Loam	9 - 28	>120	0.2 - 2.0
Birdsall Silt Loam	0 - 18	>120	0.2 - 0.63
Candice Silt Loam	0 - 18	>120	0.2 - 0.63
Caneadea Silt Loam	12 - 30	>72	0.2 - 2.0
Chagrin Silt Loam	0 - 30	>72	0.63 - 6.3
Chagrin Very Gravelly Loam	12 - 36	>72	2.0 - 20.0
Conotton Coarse Sandy Loam	18 - 72	>120	0.2 - 6.3
Dune Sand	>24	>72	>20.0
Dalton Silt Loam	18 - 72	>120	0.2 - 20.0
Ellery and Alden Silt Loam	0 - 10	>72	0.2 - 2.0
Erie Silt Loam	6 - 18	>96	0.2 - 2.0
Fredon Loam	0 - 18	>72	0.2 - 6.3
Halsey Loam	0 - 12	>120	0.2 - 6.3
Howard Gravelly Silt Loam	>24	>120	0.63 - 6.3
Langford Silt Loam	18 - 30	>120	0.63 - 2.0
Lobdell Silt Loam	0 - 18	>48	0.2 - 6.3
Mahoning Silt Loam	18 - 30	>120	0.2 - 0.63
Manlius and Lordstown	>24	>30	0.2 - 2.0
Mardin Gravelly Silt Loam	18 - 30	>120	0.2 - 2.0
Miner Silt Loam	0 - 6	>72	0.2 - 0.63
Muck and Peat	>24	>48	<0.2
Ottawa Fine Sandy Loam	>24	>120	<0.2 - 2.0
Ottawa Loamy Fine Sand	>24	>120	0.2 - 6.3
Phelps Gravelly Silt Loam	18 - 30	>120	0.2 - 0.63
Platea Silt Loam	6 - 18	>120	0.2 - 2.0
Rimer Fine Sandy Loam	0 - 30	>120	0.2 - 0.63
Scio Silt Loam	18 - 30	>72	0.2 - 2.0
Sloan Silt Loam	0 - 10	>72	0.2 - 0.63
Sloan Silty Clay Loam	0	>72	0.2 - 0.63
Trumbell Silt Loam	0 - 18	>120	0.2 - 0.63
Unadilla Fine Sandy Loam	>24	>72	0.63 - 2.0
Volusia Gravelly Silt Loam	0 - 18	>96	0.2 - 2.0
Volusia Silt Loam	0 - 18	>96	0.2 - 2.0
Wallington Fine Sandy Loam	0 - 18	>120	0.2 - 0.63
Wallington Silt Loam	0 - 18	>120	0.2 - 0.63
Wauseon FIne Sandy Loam	0 - 18	>72	0.2 - 2.0
Wayland Silt Loam	0 - 18	>72	0.2 - 2.0
Williamson and Collamer	18 - 30	>120	0.2 - 2.0
Wooster Gravelly Silt Loam	>24	>120	2.0 - 6.3

Table VI-4
Lake Erie Area Watershed
Limitations to Suitability of Soils for Stormwater
Management Alternatives

Soil Name	Ponds	Building Sites	Diversion Terraces
Allis Silt Loam	Shallowness	High water table; shallow to bedrock	Shallow to bedrock
Beach and Riverwash	Rapid permeability	Flooding	None
Beach Sand - Stabilized	Rapid permeability	Flooding	None
Berrien Fine Sandy Loam	Rapid permeability	Seasonally high water table; Unstable substratum	None
Birdsall Silt Loam	None	High water table	None
Canadice Silt Loam	None	High water table; unstable	None
Chagrin Fine Sandy	None	Unstable	None
Conotton Coarse Sandy	Rapid permeability	Flooding	None
Dalton Silt Loam	None	Seasonally high water table; unstable substratum	None
Dune Sand	Rapid permeability	Unstable	Rapid permeability
Ellery and Alden Silt	None	High water table	None
Erie Silt Loam	None	Seasonally high water table	None
Fredon Loam	Quicksand	High water table	Quicksand
Fresh Water Marsh	Flooding	Flooding	Flooding
Halsey Loam	Quicksand	High water table	None
Howard Gravelly Silt	Rapid permeability	None	None
Langford Silt Loam	None	High water table	None
Lobdell Silt Loam	None	High water table	None
Mahoning Silt Loam	None	Seasonally high water table	None
Manlius and Lordstown	Shallowness	Shallow to bedrock	Shallow to bedrock
Mardin Gravelly Silt Loam	None	None	None
Mardin and Volusia Gravelly Silt Loams	None	Seasonally high water table	None
Miner Silt Loam	None	High water table	None
Muck and Peat	Unstable	Unstable	Unstable
Ottawa Fine Sandy Loam	Rapid permeability	None	None
Ottawa Loamy Fine Sand	Rapid permeability	Unstable	None
Phelps Gravelly Silt Loam	None	None	None
Platea Silt Loam	None	Seasonally high water table	None
Rimer Fine Sandy Loam	Quicksand	Seasonally high water table	None
Scio Silt Loam	None	Seasonally high water table	None
Sloan Silty Clay Loam	None	Flooding	None
Trumbull Silt Loam	None	Seasonally high water table	None
Unadilla Fine Sandy Loam	None	None	None
Volusia Gravelly Silt Loam	None	Seasonally high water table	None
Wallington Fine Sandy Loam	Quicksand	Seasonally high water table	None
Wallington Silt Loam	None	Seasonally high water table	None
Wauseon FIne Sandy Loam	Quicksand	Seasonally high water table	None
Wayland Silt Loam	None	Flooding	None
Williamson and Collamer Fine Sandy Loams	Quicksand	Seasonally high water table	None
Williamson and Collamer Silt Loams	None	Seasonally high water table	None
Wooster Gravelly Silt Loam	Rapid permeability	None	None

OPERATION AND MAINTENANCE CONSIDERATIONS

Most stormwater control facilities or systems must be monitored and maintained regularly following construction to assure effective operation, long life and compatibility with the local setting. Table VI-5 contains a summary of key operation and maintenance considerations for the stormwater management alternatives discussed previously.

As is indicated in Table VI-5, there is range of operation / maintenance items which must be performed depending upon the type of stormwater management techniques employed. It is recommended that individual municipal stormwater management ordinance require that the enumeration of specific recommended operation and maintenance activities be be outlined by the design engineer at the time applications for permit approval are made. The designer of the facilities should be in the best position to define the maintenance requirements associated with the facilities being proposed. However, operation and maintenance plan should be reviewed in consideration of the general requirements presented in Table VI-5. The approved set of operation and maintenance activities should then be used as the basis of an on-going operation and maintenance plan. Also, provisions should be made in the appropriate ordinances or regulations to provide for effective mechanisms through which the completion of critical maintenance can be assured.

PUBLIC ACCEPTANCE OF ON-SITE DETENTION

On-site detention, also has the disadvantage of not having wide spread public acceptance. This is mostly because the individuals have to spend extra dollars to satisfy the runoff control regulations. Also, they are concerned about the safety of their children also, which are usually attracted toward the ponds. Therefore, it is highly recommended to employ multi-purpose use of detention facilities. In the minds of a community, the multi-purpose use of such a detention facility greatly improves the perception that such a facility is a justifiable expense by the public or by the private developer [APWA, 1981]. Detention ponds are excellent examples of multi-purpose adaptability. When conceived and designed artistically, they can support different kind of activities throughout the year, such as, water sports and fishing. During winter months, shallow detention ponds with a permanent pool of water provide opportunities for ice skating in some parts of the country.

Table VI-5
Operation and Maintenance Considerations

	Dredging	Debris / Sedimentation Removal	Weed Control	Insect Control	Mechanical Maintenance	Mowing	Cleaning	Repair	Inspection
Detention/Retention Basins		✱	✱	✱		✱		✱	✱
Detention/Retention Tanks				✱	✱		✱	✱	✱
Ponds	✱	✱	✱	✱				✱	✱
Parking Lot Detention							✱	✱	✱
Roof-top Retention							✱	✱	✱
Open Space Detention		✱				✱			✱
Road Embankment Detention		✱	✱	✱			✱	✱	✱
Infiltration Strips			✱				✱		✱
Infiltration Beds *		✱					✱		✱
Porous Pavement							✱	✱	✱
Open Channels **		✱	✱			✱			✱
Pipe Systems		✱					✱	✱	✱

* Includes dutch drains, seepage pits and seepage beds.

** Includes grassed and rock lined channels

A detention basin that is dry between runoff events can be used for field sports such as football, soccer, baseball, and various passive recreational pursuits such as badminton, model airplane operation, shuffleboard, croquet, and picnicking. Some detention basins may double as tennis or baseball courts. It might be difficult to convince some developers that the benefits derived from recreation outweighs the cost of the land plus construction costs. However, should the recreation area be redesigned as a multi-purpose recreational/detention basin, the cost would look insignificant compared to the cost of upgrading a storm drainage system or the amount of potential flood damages.

Detention facilities may also contribute to the protection and preservation of wildlife habitats and other natural resources. One example is a 602 ha (244 ac) tract in Chester County, Pennsylvania, where 315 homes were to be constructed. Approximately 84 ha (34 ac) of open space were provided containing two detention ponds designed to store runoff from the 100-year rainstorm. One year following the completion of the detention ponds, wildlife was observed returning to its former habitat. Geese have nested and fish have returned to the streams and newly constructed channels. The dual purpose utilization of stormwater detention facilities as wetlands represents a potential useful means of coping with the increasingly stringent wetland protection requirements and associated wetland replacement activities.

Although multiple uses are a better alternative for securing the community acceptance, maintenance costs for such facilities may be higher. Therefore, when considering multiple uses, it is important to look at all the associated costs and intangible benefits, to determine if it is practical to proceed with the multiple use concept.

SAFETY CONSIDERATIONS

A survey conducted by APWA in 1980, based on 325 respondents, revealed that there have been two drownings reported at the detention facilities. It is therefore, very essential to take precautions in design and selection of storm water management alternatives, to minimize hazards. Embankment slopes, railings, fencing and other features are obvious considerations. The importance of designing and constructing outflow structures and dams with safety considerations in mind should never be ignored. In general, the approaches that can be used to promote safety are [APWA, 1981]:

1. Keep people off the detention facility site
2. Provide escape aids
3. Make the onset of the hazards gradual
4. Eliminate the hazards

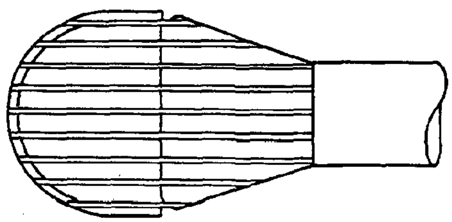
The designers and reviewers of stormwater control facilities, particularly those using detention / retention facilities should pay particular attention to incorporating appropriate safety features in the design of the facilities.

Special attention must be given to the design of outflow structures to satisfy the safety considerations. Water currents constitute a distinct hazard to persons who enter a detention pond or basin during periods when stormwater is being discharged. The force of the currents may push a person into an outflow structure or may hold a victim under the water where a bottom discharge is used. Several features designed to either eliminate or reduce such hazards are illustrated in Figures VI-20 and VI-21.

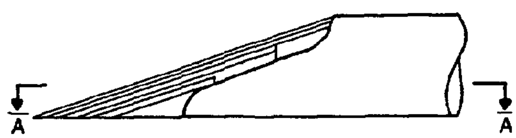
Figure VI-20 illustrates two versions of designs for non-submerged outlets: 1) curvilinear trash/safety racks for standard flared end sections and 2) narrow flume outlets. Both of these designs represent methods which tend to reduce the potential for persons to be drawn into or trapped against the outlet devices.

Figure VI-21 presents suggested safety features for submerged outlets: 1) outflow velocities and hence the associated hazards can be reduced through the use of a porous dam type of outlet facility; and 2) the illustrated safety rack for submerged outlets reduces the entrapment potential and provides a means of egress from the basin. As is also illustrated in Figure VI-21, drowning hazards can also be reduced by using a floating inlet for a basin outlet structure. The floating inlet reduces the drowning hazard by eliminating the water force which could trap a person at the outflow structure.

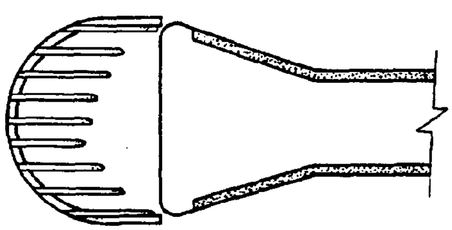
Table VI-20
Suggested Safety Features for Non-Submerged Outlets



Plan View



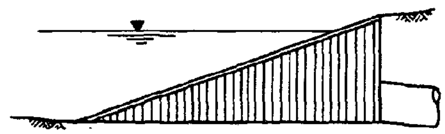
Elevation



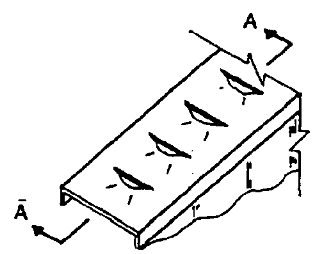
Section A - A

Curvilinear Trash/Safety Rack for Standard Flared End Sections

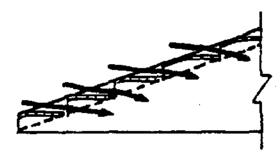
Plan View



Elevation



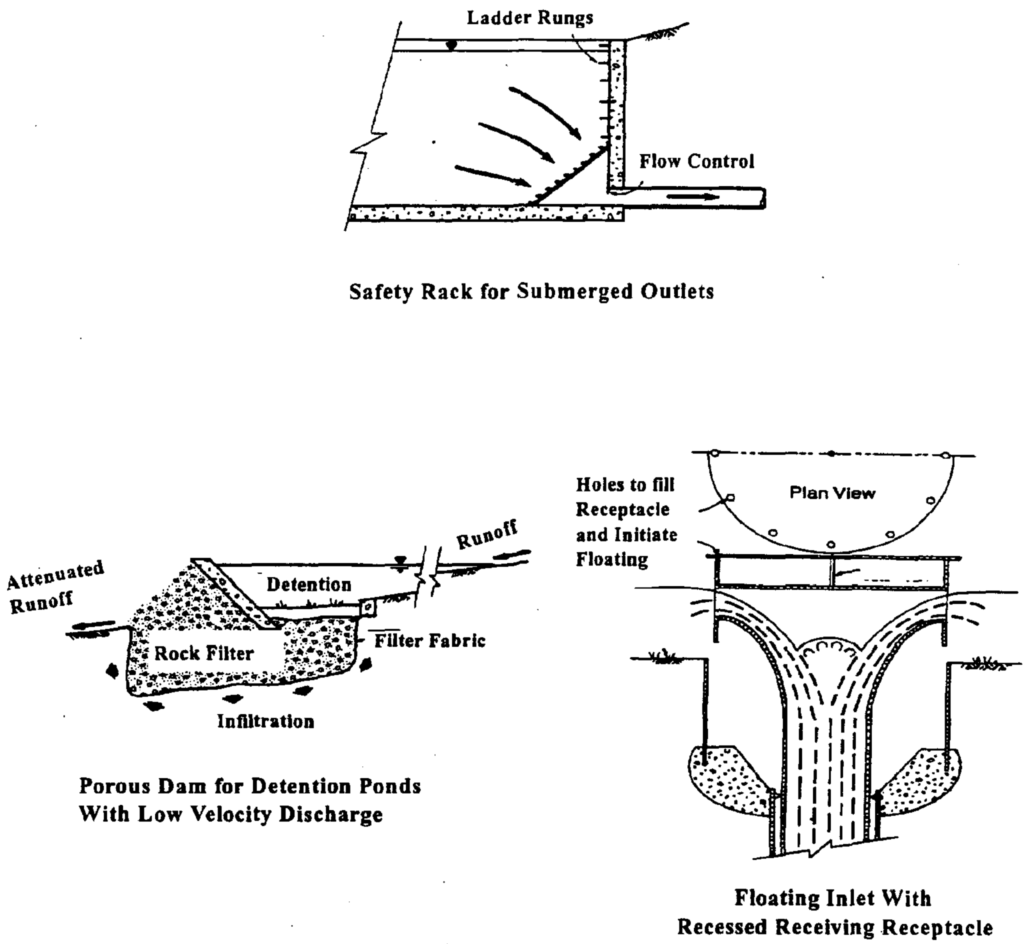
Isometric Detail of Louver



Section A - A

Narrow Flume Outlet For Detention Ponds

Figure VI-21
Suggested Safety Features for Submerged Outlets



DISTRIBUTED STORAGE

GENERAL

The stormwater management techniques discussed thus far have been geared primarily to on-site control methods. It is likely that on-site controls will be the predominant form of stormwater management in the Lake Erie watershed. Off-site, distributed storage is, however, an alternative or adjunct to on-site control techniques which should be recognized and considered for use where appropriate. Simply defined, distributed storage is the process of utilizing the most suitable site or sites for regional detention facilities.

The combination of on-site detention and distributed storage approaches may significantly improve the capability of land developers and communities to control stormwater on a watershed basis. Distributed storage may also offer a means of accommodating development in a manner which minimizes total costs and optimizes land utilization through the sharing of a single, strategically located detention or retention facility. Finally, the use of distributed storage may increase the feasibility of dual or multi-purpose facilities. For example, certain recreation areas might easily be used to provide temporary stormwater storage; natural or artificial ponds and lakes can serve both recreation and stormwater management objectives; and stormwater management facilities may be constructed as replacement wetlands.

SUMMARY

The institution of stormwater management regulations throughout the watershed will require that land developers include provisions in their land development plans to limit increases in the volume of runoff and to control peak rates of stormwater discharges to levels specified in the local ordinances. These standards will be presented as performance standards. That is, the standards will set limits on the peak rate of discharge permitted from the development site without specifying the exact methods to be used in order to meet the standards. The owner of the development will be afforded a high degree of flexibility in the selection and design of the specific measures to be incorporated into the design of the development. This will permit the developer to select and arrange the various available control techniques in a manner that is most efficient for the particular information and that best accommodates the intended use of the development.

Nevertheless, the various stormwater control techniques offer differing degrees of benefit. For example, measures such as the preservation of pervious areas, the use of filter strips and buffers, and the use of vegetated swales offer the following significant advantages:

1. Minimization of total runoff volumes

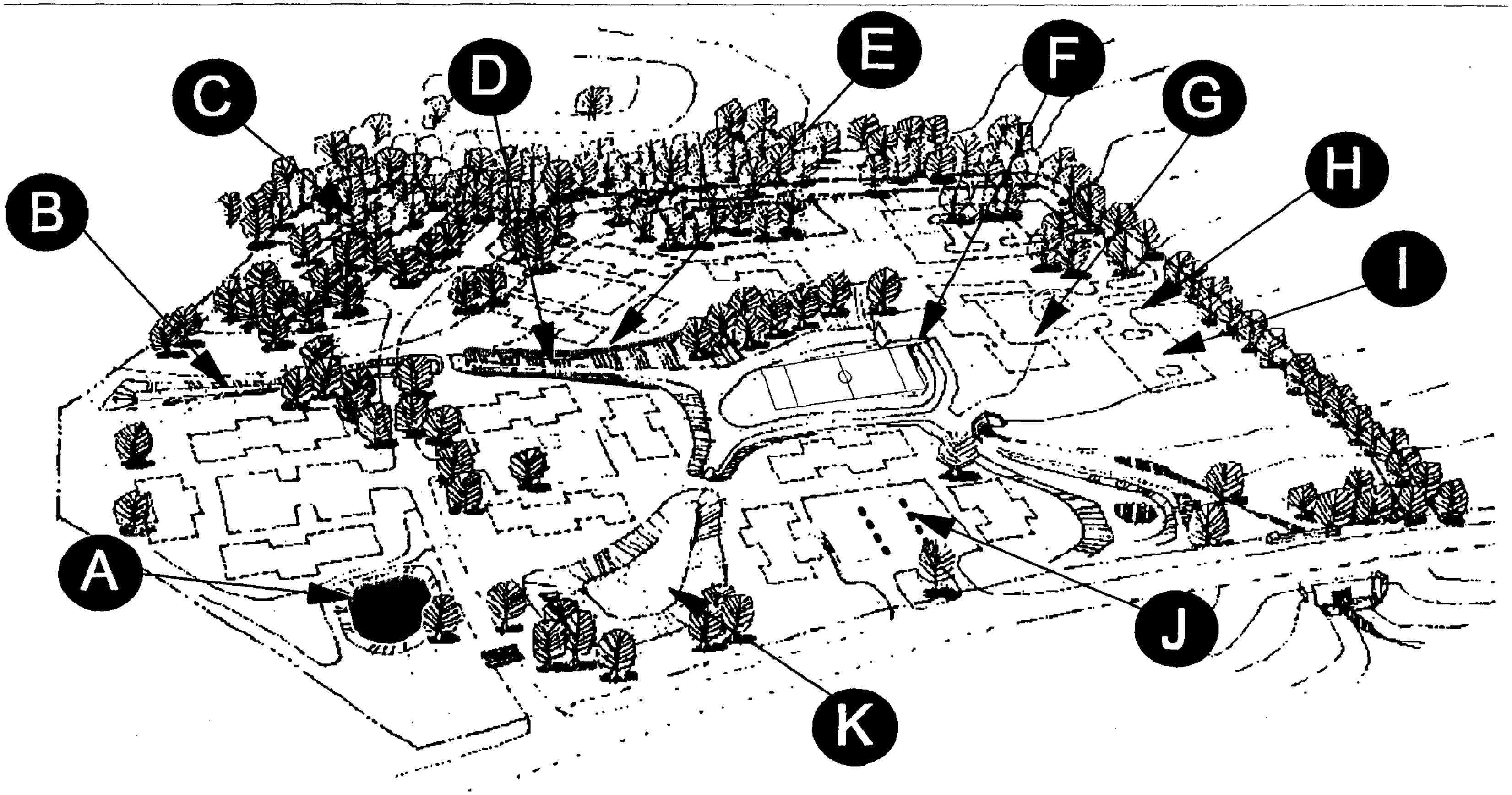
2. Promotion of aquifer recharge
3. Stormwater pollution reduction
4. Ease of construction and maintenance
5. Low construction and maintenance costs
6. Preservation of open space

The opportunity for realizing these benefits is lost if no effort is made to utilize these techniques and the stormwater performance standards are satisfied solely through the construction of detention facilities. It is important, therefore, that the land developers be encouraged to make use of the full range of available control techniques in an integrated approach that maximizes the attributes of each. To that end, the municipal stormwater ordinances should encourage the land developers to select the general types of stormwater controls used in his/her stormwater management plan in the general order of preference:

1. Maximization of infiltration on-site by minimizing land disturbance, maximizing the amount of pervious surfaces incorporated in the development, and creating vegetated strips and buffer areas.
2. Flow attenuation through the use of open vegetated swales, rock lined channels, and natural depressions
3. Stormwater detention / retention structures (dry, wet, multi-purpose)

An example of a land development that employs the broad range of applicable control techniques is present in Figure VI-22. The concept illustrated in Figure VI-24 is an approach to providing stormwater management techniques in a manner that incorporates them into the overall design of the development while using the flow and pollution control capabilities of each technique in an integrated stormwater management and overall land development plan.

Figure VI-22
Example of Development Integrating Variety of Stormwater Control Techniques



Techniques Employed

A:	Wet detention pond	F:	Multi-use dry detention area
B:	Grassed swale	G:	Dutch drains under roof eves
C:	Oringinal growth woodlands preserved	H:	Pervious surface walkways
D:	Rock-lined channel	I:	Parking lot detention storage
E:	Grassed strips	J:	Grassed strips in parking area