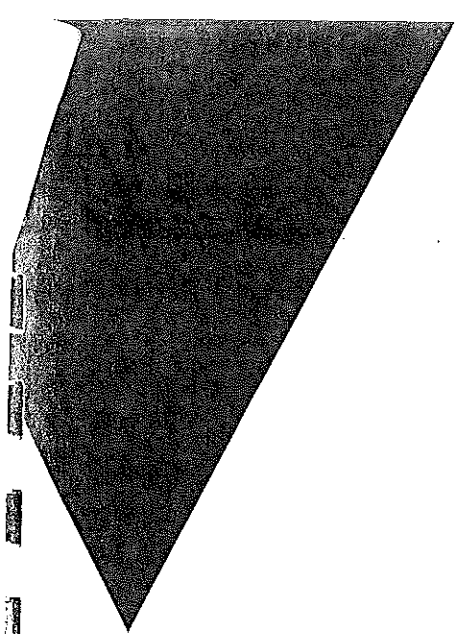


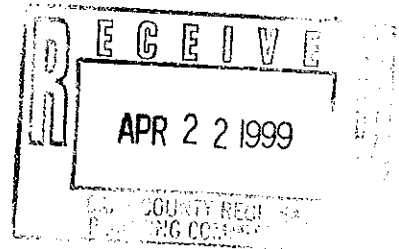


VIERBICHER
ASSOCIATES

NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG, WISCONSIN

Vierbicher Associates, Inc.
and
Applied Ecological Services, Inc.

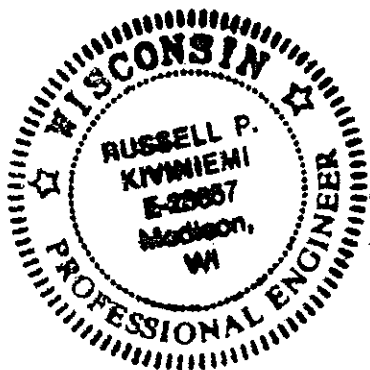
▼ ENGINEERING
▼ ARCHITECTURE
▼ ENVIRONMENTAL
▼ SURVEYING/MAPPING
▼ COMMUNITY DEVELOPMENT



Nine Springs Neighborhood Storm Water Management Plan

Prepared For:
City of Fitchburg
2377 Fish Hatchery Road
Fitchburg, WI 53711

Prepared By:
Vierbicher Associates, Inc.
6200 Mineral Point Road
Madison, WI 53705-4505
and
Applied Ecological Services, Inc.
P.O. Box 256, 17921 Smith Road
Brodhead, WI 53520-0256



Russell P. Kiviniemi
6/23/98

December 1997 - Draft Report
Revised May 1998 - Draft Report
Revised June 1998 - Final Report

EXECUTIVE SUMMARY

This report represents a comprehensive storm water management plan for the proposed City of Fitchburg Nine Springs Neighborhood Area. The report will serve as a comprehensive guide for the development of a storm water management system within the Nine Springs Neighborhood Plan Area. This Plan incorporates several storm water management elements: storm water quantity, storm water quality, infiltration/hydrogeology, ecological resources, including wetlands, and springs. The Plan will provide a basis for local flood control planning and design, water quality improvements and design, increased infiltration and groundwater recharge, and improve and mitigate the current degradation of existing ecological resources, as well as a guide for proceeding with final engineering and design.

In March 1995, the City of Fitchburg adopted the revised General Land Use Plan as the City's long-range land use policy. The General Land Use Plan includes a statement of community goals and policies, generalized land use and circulation plans, and a staging plan for future expansions of the urban service area. The Plan has a general time frame of 10 to 20 years.

One of the key recommendations of the revised General Land Use Plan is to concentrate the City's resources in the development of the Nine Springs Neighborhood. The Nine Springs Neighborhood is identified as the next logical addition to the Central Urban Service Area.

The Nine Springs Neighborhood Plan was completed in February 1997. This Plan was submitted to both Wisconsin Department of Natural Resources and Dane County Regional Planning Commission for review and comment. Both governing agencies recommended that a comprehensive storm water management plan be done for the Nine Springs Neighborhood Area. On September 2, 1997, the City of Fitchburg entered into a contract and hired Vierbicher Associates, Inc. to prepare a comprehensive storm water management plan for the Nine Springs Neighborhood.

The intent is that, after adoption of both the Nine Springs Neighborhood Plan and Nine Springs Neighborhood Storm Water Management Plan, the City of Fitchburg will petition the Dane County Regional Planning Commission for expansion of the Central Urban Service Area to allow the extension of sanitary sewer service and development into the Planning Area.

The primary objectives of the City of Fitchburg Nine Springs Neighborhood Storm Water Management Plan are to enhance, protect, and preserve the unique environmental and ecological characteristics of the Nine Springs Creek, E-Way Corridor, existing wetlands and springs by utilizing wet detention basins, grass and prairie grass infiltration systems, and existing wetlands in order to:

- Reduce to the maximum practical extent, the public and private capital expenditures for construction, operation and maintenance necessary to control excessive volumes and rates of storm water runoff and constituent pollutant discharges as the City develops and grows.
- Prevent increases in storm water runoff and downstream flooding.
- Minimize water quality and ecological degradation and pollutant discharge loads.
- Improve and preserve water quality in all water bodies.
- Reduce erosion, sedimentation, habitat and ecological loss.
- Maintain natural base flows and promote groundwater recharge by encouraging creative and cost effective storm water infiltration methodologies.
- Protect and enhance biological, fish and wildlife habitat.
- Minimize negative impacts to wetlands, springs and the environment.
- Provide opportunities for multiple use of drainage and storm water management facilities.
- Enhance the natural beauty of the landscape by providing economical, safe, aesthetically pleasing and socially acceptable drainage facilities within proposed new developments.
- Protect and enhance recreational opportunities.
- Secure other benefits associated with the proper management of storm water runoff.

Policies that will fulfill these objectives are set forth in Section IV., Goals and Objectives. These goals and objectives are addressed throughout the entire Plan document.

Storm water drainage facilities are an essential part of the development of any municipality. As an area develops from rural to urban land uses, culverts and drainageways which had been adequate for rural storm water runoff become overloaded, causing flooding. Different pollutants are generated from urban runoff than from rural runoff. The primary function of an urban storm water management system is to protect and enhance the water and ecological resources of the City and minimize economic loss and inconvenience caused by periodic flooding. The major storm water facilities that are required to control storm water quantity and quality runoff from a completely urbanized watershed are described. Detention ponds are designed for a 100-year storm event and 60% to 90% reduction of typical storm water pollutants, while storm sewer pipe conveyance systems are designed for a 10-year storm event.

The Storm Water Plan included a general overview of the ecological condition of the vegetation/land cover types within the Nine Springs Neighborhood Planning Area utilizing aerial photography and field investigations. This work also included a wetland delineation within the Planning Area. Wetland delineation techniques and criteria for evaluation of the results followed the "Army Corps of Engineers Wetland Delineation Manual 1987".

An infiltration field testing program was undertaken to identify the existing rates of infiltration at different locations within the watershed. Infiltration has been identified and known to be a key component in reducing storm water runoff volumes and in the overall management of the water balance within the Planning Area. Results and observations of the field testing program offer strong evidence for the creation of macropores to increase infiltration rates. The presence of large earthworms and night crawlers at most of the test sites suggests that macropores are associated with worm burrows.

Macropores and earthworm burrows are most easily and economically created through the establishment of prairie and grasses infiltration areas. The Storm Water Management Plan provides an extensive multi-stage storm water treatment train system utilizing grass swales and drainageways, prairie grass filtration and buffer areas, wet detention basins, existing and proposed wetland areas. This multi-stage storm water management, treatment and infiltration system is the most economical to construct and for the City to maintain. *Storm water runoff pollutants and volumes will be significantly reduced by proposed Storm Water Management System Best Management Practices.* The infiltration system proposed for this Planning Area exceeds the amount of infiltration that is currently being provided in its existing land use state.

A brief outline of the steps involved in the preparation of the Nine Springs Neighborhood Storm Water Management Plan is presented below:

1. Determine watershed and subwatershed boundaries for use in hydrologic, hydraulic, storm water management and water quality analysis.
2. Identify existing water quality and storm water conveyance and management problems.
3. Identify ecological conditions of vegetation/land cover types and delineate wetlands.
4. Perform infiltration field testing program to identify infiltration areas and infiltration best management practice methodologies for storm water management.
5. Establish the location and size of storm water management and storm water conveyance facilities.

6. Analyze and estimate the pollutant loads and storm water runoff quantity under existing land use conditions.
7. Analyze and estimate the pollutant loads and storm water runoff quantity under fully-developed conditions.
8. Analyze and estimate the pollutant loads and storm water runoff quantity under fully-developed conditions with storm water management facilities and best management practices.
9. Estimate the costs of storm water management facilities and best management practices in order to provide a guide for development of a funding/finance program.
10. Determine a prioritized schedule over a 15-year period for implementation of recommended best management practices and storm water management facilities based on the Nine Springs Neighborhood Plan phased development sequence.
11. Based on the guidance provided by City of Fitchburg and staff, establish a set of storm water management goals and policies for the successful implementation and completion of this Plan.

TABLE OF CONTENTS

<u>Description</u>	<u>Page</u>
I. Introduction	1
II. Project Description	3
A. Scope of Plan	3
B. General Description	5
C. Sources of Problems	8
D. Concerns	10
E. Benefits	11
F. Process of Analysis	12
III. Elements of Plan	14
IV. Goals and Objectives	16
V. Natural Resource Cover Mapping - Applied Ecological Services, Inc.	17
A. Vegetation Land Cover Types	
1. Introduction	
2. Methods	
3. Results	
4. Recommendations	
B. Wetland Delineation	
1. Introduction	
2. Methods	
3. Results	
4. Discussions	
5. References Cited	
6. Attachment 1	
VI. Infiltration/Hydrogeology	18
A. Introduction	18
B. Methods	21
C. Results	27
D. Discussion and Conclusions	29
VII. Storm Water Quantity	33
A. General	33
B. Watersheds	34
C. Hydrology/Hydraulics	34
D. Storm Sewer Hydraulics	39
E. Wet Detention Pond Water Quantity Control	42
F. Water Quantity Detention Pond Alternatives	45
G. Detention Pond Open Space Compatibility	52

<u>Description</u>	<u>Page</u>
VIII. Storm Water Quality	55
A. General	55
B. Erosion and Sediment Control	58
C. Treatment Based Storm Water Quality Control	69
D. Storm Water Quality Modeling	71
IX. Storm Water Quantity/Quality Assessment	74
A. Land Use Analysis	74
B. Hydrologic/Hydraulic Runoff Analysis	74
C. Water Quality Analysis Pollutant Loading Summary	75
D. Runoff Analysis Summary After Storm Water Quantity Management Practices	75
E. Pollutant Loading Summary Analysis After Storm Water Quality Management Practices	76
F. Benefit Cost Effectiveness Assessment of Recommended Best Management Practice Controls	77
G. Ranking Assessment of Recommended Best Management Practice Controls	78
H. Tables 1 - 64: Subwatersheds A-H	81
I. Tables 65-72: Entire Watershed Summary Tables	113
X. Best Management Practices	118
A. General	118
B. Recommended Structural Best Management Controls	119
C. Recommended Non-Structural Best Management Controls	126
XI. Funding Options	136
A. State/Federal Grants and Loans	136
B. Development Charges	136
C. Fee-in-Lieu of On-Site Detention/Retention	137
D. Special Assessments	137
E. Plan Review and Inspection Fees	138
F. Storm Water Service Charges	138
G. Taxation	139
H. Bonding	140
I. Storm Water Utility	140
XII. Implementation and Summary Recommendations	143
A. Implementation Strategy	143
1. Establish Storm Water Utility District	143
2. Implement an Ecological System Restoration and Management Program	144
3. Implement Effective Ecological Protection Regulations	144
4. Encourage Reduced Setbacks	145
5. Reevaluate Street Width Requirements	145

Description	Page
6. Encourage Natural Drainage Designs	145
7. Encourage Native Vegetation for Landscaping	146
8. Reduce Parking Requirements	146
9. Encourage Cluster Developments	146
10. Wastewater Service Areas	146
11. Provide Effective Wet Storm Water Detention	147
12. Construct Storm Sewers Only Where Necessary	147
13. Educate Residents About Natural Drainage Approaches	147
14. Identify Appropriate Floodplain Uses and Zoning	148
15. Implement Open Space Opportunities	148
16. Implement Comprehensive Storm Water Management Ordinance	148
17. Wellhead Protection	149
B. Cost of Implementation	150
1. Immediate Improvements - 1 to 5 Years±	150
2. Intermediate Improvements - 5 to 10 Years±	151
3. Ultimate Future Improvements - 10 to 15 Years±	151
C. Implementation Benefits	152
1. Minimized Erosion and Sedimentation	153
2. Improved Water Quality	153
3. Protected Ecosystems	153
4. Minimized Public and Private Costs	153
5. Improved Appearance	154
6. Enhanced Property Values	154
D. Summary of Recommendations	154
1. Natural Resources	154
2. Infiltration/Hydrogeology	155
3. Storm Water Quantity	155
4. Storm Water Quality	156
5. Structural BMPs	157
6. Non-Structural BMPs	157
7. Funding/Financing Options	158

Tables

Table 1	Classification System for Vegetation/Land Cover Types	Appendix A
Table 2	Existing Land Use	7
Table 3	Proposed Land Use	8
Table 4	Air-Entry Permeameter Test/Locations	25
Table 5	Summary of Infiltration Testing Results	28
Table 6	Runoff Coefficients	37
Table 7	Equivalent Curve Numbers to Runoff Coefficient for a 100-Year Storm	38
Table 8	Expected Inundation Time for Recreational Facilities Located Around Detention Basins	53
Table 9	Pollutants in Wisconsin Urban Runoff	57
Table 10	Benefits of Well Designed Wet Detention Ponds	70

<u>Description</u>	<u>Page</u>
<u>Figures</u>	
Figure 1	Vegetation Land Cover Types Appendix A
Figure 2	Soil Survey of Nine Springs Parcel Appendix A
Figure 3	Wisconsin Wetland Inventory Map Appendix A
Figure 4	Routine Wetland Determination ID Locations Appendix A
Figure 5	Air-Entry Permeameter 23
Figure 6	Comparative Depth of Infiltration 31
Figure 6A	Root Systems of Prairie Plants 32
Figure 7	Free Flow Skimmer with Restricted Outlet 48
Figure 8	Detention Pond Types 49
Figure 9	Detention Pond Outlet Structure 50
Figure 10	Dry Pond Trash Rack Design 51
Figure 11	Park Development Options 54
Figure 12	Sediment and Skimming Structures 68
<u>Appendices</u>	
Appendix A:	Section V-Natural Resource Cover Mapping by Applied Ecological Services, Inc.
Appendix B:	Maps
	Map #1 USDA/SCS Soil Survey Map
	Map #2 Permeameter Testing Locations
	Map #3 Watershed/Subwatershed/Subareas
	Map #4 Recommended Storm Water Management Facilities
Appendix C:	Soil Permeability Test Results
Appendix D:	City of Fitchburg-Chapter 27 Erosion Control and Storm Water Management Ordinance
Appendix E:	Sample Wellhead Protection Ordinance
Appendix F:	Sample Storm Water Management Ordinance
Appendix G:	Best Management Practices Fact Sheet
Appendix H:	Glossary
Appendix I:	References

I. INTRODUCTION

The purpose of this Nine Springs Neighborhood Storm Water Management Plan will be to minimize storm water runoff, encourage storm water infiltration, prevent property damage and hazardous conditions, prevent erosion, reduce sediment and nutrient deposition in the storm water conveyance system and waterways, protect the quality of groundwater, protect the water supply aquifer, preserve the Nine Springs Creek E-Way Corridor as an asset to the community, and minimize the negative impact of existing and future storm water discharges to wetlands, springs, and the environment. By developing this land with the proper storm water management system in place, less soil erosion and storm water runoff pollutants will be discharged to Nine Springs Creek and Swan Creek.

Streams, drainageways, lakes, environmental corridors, and wetlands are valuable natural features in providing picturesque variations and buffers in a sometimes monotonous landscape. While the principal natural function of stream systems is to drain runoff and floodwater from the landscape, streams and rivers also provide for fishing, aquatic and wildlife habitat, water supply, groundwater recharge, nature study, and aesthetic enhancement.

Wetlands--swamps, marshes, bogs, meadows, and fens--also are common elements of the landscape, often bordering lakes and streams. Wetlands filter contaminants from agricultural and urban runoff. Wetlands store vast quantities of floodwater, releasing it slowly to protect downstream areas. Wetlands also help to maintain consistent base flows and water levels in streams and lakes and some recharge underground aquifers. Finally, wetlands are highly productive ecological systems, providing habitats for exceptionally diverse communities of plants and wildlife.

Because of their predominance and location in the landscape, however, wetlands have historically been altered and destroyed by man. Wetlands were drained and filled to accommodate agricultural and urban development. Streams were straightened and deepened to speed the drainage of runoff and to lower water tables. Lakes functioned as sinks for sediments, nutrients, and other pollutants, resulting in severe water quality impairments.

The Nine Springs Neighborhood Plan was prepared in accordance with the City of Fitchburg's adopted and revised General Land Use Plan, March 1995, as the City's long-range land use policy document. One of the key recommendations of the revised General Land Use Plan is to concentrate the City's key resources in the development of the Nine Springs Neighborhood. The Nine Springs Neighborhood has been identified as the next logical addition to the Central Urban Service Area.

The Nine Springs Neighborhood Plan was prepared to provide guidance regarding the type of development, development densities, the circulation system, and other public facilities and services. The intent is that, after adoption of the Nine Springs Neighborhood Plan, the City of Fitchburg will petition Dane County Regional Planning Commission for expansion of the Central Urban Service Area to allow the extension of sanitary sewer service into the Planning Area.

The Neighborhood Plan and Storm Water Plan will serve as a guide for both the City and private land owners and developers in fostering development of a well-designed and efficient neighborhood that serves the needs of residents and businesses; and improves and preserves the high quality of the natural environment. The guiding principles in developing both plans has been to enhance, protect and preserve the unique environmental characteristics of the Nine Springs Creek E-Way Corridor.



Introduction

Project Description

II. PROJECT DESCRIPTION

The Nine Springs Neighborhood Storm Water Management Planning Area is part of the Yahara Monona Priority Watershed. In 1988, the Wisconsin Department of Natural Resources (WDNR) designated the Yahara Monona Watershed as a Priority Watershed under the Wisconsin Nonpoint Source Pollution Abatement Program. In 1992, the Yahara Monona Priority Watershed Project Plan (Dane County Regional Planning Commission, 1992) was published to guide the implementation of the project.

Adopted recommendations of the Nine Springs Neighborhood Storm Water Management Plan will become refinements to the Yahara Monona Priority Watershed Project Plan and will guide site specific implementation of storm water management practices within the proposed Nine Springs Neighborhood. This Plan will be used to assist the City of Fitchburg in preparation of an Urban Service Area Adjustment Request. The Plan utilizes the best available methodology designs and management practices to encourage infiltration; reduce velocities and volume of storm water runoff, reduce pollutant loading, and minimize impacts on wetlands, springs and other ecological and natural features.

Nine Springs Neighborhood is located within the Nine Springs Watershed and Swan Creek Watershed. Portions of the planning area lie within and adjacent to the Nine Springs Creek Environmental Corridor (E-Way). The proposed storm water planning area includes portions of the watershed outside the neighborhood land planning area that convey storm water runoff through the land planning area to Nine Springs Creek and Swan Creek.

A. Scope of Plan

Storm water management refers to all activities relating to the control and management of rainfall runoff including subsurface groundwater and surface water drainage, flood control and water quality. It is also now widely recognized that storm water management is more than a local issue; it requires the consolidation and coordination of the many independent efforts into a system that recognizes the regional nature of storm water, flood water runoff, groundwater, and water quality pollutant loads.

The storm water management plan establishes the policy guidance basis for the Nine Springs Neighborhood's storm water management program and addresses the following objectives:

- prevent increases in storm water runoff and downstream flooding
- minimize water quality degradation and pollutant discharge loads
- minimize downstream channel erosion, habitat and ecological loss
- maintain natural base flows and recharge groundwater by encouraging storm water infiltration

- minimize negative impacts to wetlands, springs and the environment
- provide opportunities for multiple use of drainage and storage facilities
- provide for economical, safe, aesthetic, and socially acceptable drainage within new developments

The recommended storm water management philosophy encourages storm water systems which mimic as closely as possible the runoff process of the site in its natural state by preserving natural storage, conveyance, and filtering mechanisms. In addition to achieving the listed objectives, this approach should reduce drainage system construction costs by minimizing the need for expensive capital improvements to convey, store, and treat increased runoff volumes and rates.

An important need to effectively manage storm water is information on existing conditions, problems, and opportunities. The plan reflects the recommendations and results of previous studies and plans. The storm water plan identifies local watershed boundaries and natural and man-made drainage features such as ditches and culverts. The plan also identifies locations of significant natural resource areas, natural storage areas, including depressions, woods, prairie grasses, and wetlands. The plan describes existing problems related to drainage, local flooding, sedimentation, degradation of existing natural resources, and storm water quality. Based on existing and proposed conditions, the plan proposes effective requirements for existing agricultural uses and new development, remediation needs, and opportunities for regional water quantity and quality control storm water management facilities.

Strategies that address the area's unique climate, topography, natural resources, hydrogeology, and land use patterns are necessary. By making use of regulatory, land use planning, and educational approaches whenever feasible, rather than costly structural solutions, Fitchburg can greatly reduce the ultimate costs of implementing the storm water plan.

Management techniques are similar from one part of the watershed area to another, but are accomplished with different methodologies. In newly developing or redeveloping areas, the program emphasizes land use planning approaches using site plan and subdivision review to require specific storm water management actions. In agricultural and developed areas, the use of police powers and regulatory powers to abate, enjoin, or criminalize illicit discharges and the dumping of pollutants into the storm water system is critical.

Public education can reduce discharges of old motor oil, household wastes, litter, anti-freeze, deicing chemicals, yard fertilizers, and agricultural herbicides, pesticides and fertilizers. More regular and improved inspections, operations and maintenance are necessary to reduce illegal

discharges and infiltration into the storm water drainage system. Repair or replacement of structural controls will also be necessary, and new controls may augment storm water system capacity or correct deficiencies in both agricultural, developed and proposed development areas.

B. General Description

The proposed Nine Springs Neighborhood is located in the northeast quadrant of the City of Fitchburg, and consists of land north and south of Lacy Road, west of U.S. Highway 14, east of the existing Fitchburg Center Development, and south of the Nine Springs Creek Environmental Corridor.

Nine Springs Neighborhood is located within the Yahara River Valley created during the last ice age. Glacial deposits dammed up large preglacial valleys, forming a chain of large lakes and wetlands. The glacier produced the natural resources the City enjoys today. As the glacier retreated, the Yahara River and its tributaries, such as Nine Springs Creek and Swan Creek, were formed. The fertile soils deposited in the river valley contributed to the establishment of agricultural activities in the Nine Springs area during the mid 1800s.

The physiography and topography of Nine Springs Neighborhood are characteristic of the rolling morainal terrain in the central portion of Dane County east of the "driftless" (unglaciated) area. Nine Springs Neighborhood is located in the Yahara River Basin, a ground moraine area consisting of relatively flat or undulating glacial deposits, including many wetland areas formed by the glaciers from 10,000 to 20,000 years ago. Topographic relief within the watershed plan area ranges from about 1040 feet above sea level southwest of McGaw Park, down to 850 feet above sea level at Nine Springs Creek.

The surface geology of the Nine Springs Neighborhood consists primarily of morainal and glacial outwash deposits from the most recent glaciation. Several drumlins (elongated hills) are found in the area. The subsurface geology consists of Cambrian sandstones and Ordovician bedrock, such as Prairie du Chien Dolomite and St. Peter Sandstone deposited 400 to 600 million years ago. Ordovician deposits are predominant in the western half of Fitchburg. The Cambrian sandstones are a significant source of groundwater.

The upland soils in the Nine Springs Neighborhood are primarily silt loam soils of the Plano-Ringwood-Griswold Association and the Dodge-St. Charles-McHenry Association (USDA 1978). These soils were formed on sandy loam glaciated tills. These soils are moderately- to well-drained, are generally suitable for development, and have 2 to 6% slopes. The same soils that are suitable for development also tend to be prime agricultural soils.

Soils in steep slope areas include Griswold, Kidder and Whalan loams; and McHenry silt loams. Soil types with 5 to 12% slopes have moderate limitations to development, where as soil types with 12 to 20% slopes have severe limitations due to high erodibility. There are no areas within the Nine Springs Neighborhood that have severe slope limitations. Moderate and severe slope limitations do not imply that these areas cannot be developed, but indicate that additional engineering, design and construction control practices are warranted in those areas.

Soils within the wetlands and floodplains of Nine Springs and Swan Creeks include alluvial land, marsh, mucks (Houghton and Palms), silty clay loams (Wacousta and Sable) and silt loams (Orion and Radford). All of these soil types have very severe limitations to development due to high compressibility, very low bearing capacity, seasonal high water table and occasional flooding. Development is usually unsuitable in areas of very severe limitations. Elburn, Troxel and Virgil silt loams are located near creeks and drainageways. These soils also have severe limitations to development due to occasional flooding. In areas with severe limitations due to occasional flooding or steep slopes, proper development can occur if the design of the development takes into account these site limitations.

The primary surface water bodies in the Nine Springs Neighborhood are Nine Springs Creek and Swan Creek. Drainageways convey storm water runoff to these water bodies. Nine Springs Creek supports a diverse fishery including warm-water sport fish and forage populations, as well as trout from the Nevin Fish Hatchery. The fishery of Swan Creek is limited to forage populations, such as bluntnose minnows and johnny darters. Nine Springs Creek flows from west to east along the neighborhood northern boundary, and Swan Creek flows west to east along the neighborhood southern boundary. Much of the land area along Nine Springs Creek and Swan Creek lie within the 100-year floodplain. Most of the significant wetlands are associated with floodplains.

1. Environmental Corridors

Environmental corridors identified in the City of Fitchburg Land Use Plan, Nine Springs Neighborhood Plan and this Storm Water Management Plan form continuous systems of open space that include environmentally sensitive lands and natural resources requiring protection from disturbance and development, and lands needed for open space and recreational use. They are based mainly on drainageways and stream channels, floodplains, wetlands, and other resource lands and features. Environmental corridors are used to address the multiple concerns of drainage, water quality, recreation and open space.

Protection and preservation of environmental corridors contribute to environmental protection in general, and specifically to water quality through reduction of nonpoint source pollution and protection of natural drainage systems by assisting to increases filtration. In addition to protecting natural drainage systems in urban areas, environmental corridors can protect and preserve sensitive natural areas, such as springs, wetlands, floodplains, woodlands, steep slopes, and other areas that would impair surface or groundwater quality if disturbed or developed.

2. Existing Land Use

The Nine Springs Neighborhood currently consists of primarily undeveloped farm land with several clusters of low density residential property along Lacy Road, Syene Road, and Clayton Road. There are several light industrial businesses within the Syene Road area, including H&M Distributing, located at West Clayton Road, and Perkins Oil Warehouse and Distributing Facility on Syene Road. West of the Nine Springs Neighborhood is Fitchburg Center, which is an approximately 382-acre planned mixed use development.

Approximately 562 acres within Nine Springs Creek are owned by Dane County, the City of Madison, and the City of Fitchburg as part of the Nine Springs Creek E-Way Corridor. An additional 276 acres of adjoining land are owned and managed by the WDNR.

Table 2 Existing Land Use in Nine Springs Neighborhood: 1997	
	Acres
Low Density Residential/Farmsteads	150
Industrial/Commercial	20
Street and Railroad R.O.W.	140
Woodlands	60
Crop and Pasture	462
Environmental Corridor	427
Total:	1259

3. Proposed Land Use

The Nine Springs Neighborhood consists of a total of 1,259 acres, of which approximately 427 acres are proposed for environmental corridor and would not contain any residential, commercial and business park development. The remaining 832 gross acres are proposed for a combination of residential, commercial and business park development.

The amount of developable land in the Nine Springs Neighborhood is approximately 558 net acres. The net acreage assumes that 33% of the gross land area, exclusive of environmental corridors, will be used for streets, railroad right-of-way, public utility easements, storm water management and conveyance, schools, parks, and other public purposes.

Table 3 Proposed Land Use in Nine Springs Neighborhood		
	Gross Acres	Net Acres
Low Density Residential (ave. 3.25 dwelling units/net acre)	177.0	118.6
Medium Density Residential (ave. 7.0 dwelling units/net acre)	315.0	211.1
High Density Residential (ave. 15 dwelling units/net acre)	135.0	90.5
Commercial	35.0	23.5
Business Park	170.0	113.9
Total Developable Acres	832.0	557.6
Environmental Corridor	427.0	427.0
Total Acres:	1,259	

C. Sources of Problems

Daily drainage problems are often highly visible and politically require immediate attention. Long-term drainage problems, on the other hand, often go unnoticed. The problems tend to evolve over a long period of time, then appear suddenly when a flood occurs. At this point, however, only the flooding effects are addressed, rather than the flooding causes. Solving future storm water problems will require the planning, financing, construction, inspection and maintenance of a storm water management system.

To dispose of excess storm water and improve soil drainage so that the land surface can continue to be farmed or developed; swales, ditches, and canals have been excavated in order to channel storm water runoff more rapidly away from farm, residential, or other desirable lands. But more rapid removal of surface runoff at the local level means a greater flow intensity, velocity, and impact on downstream ditches, canals, drainage systems, wetlands, E-Way, and elsewhere in the area.

The faster that water flows from high elevations, the more intense are the flow impacts on downstream points within areawide drainage systems. When more water reaches an outlet point at the downstream edge of any drainage area than can be accommodated by the outlet within a given time period, the drainageways upstream of the outlet will back up and overflow, causing surface flooding on low-lying lands.

Runoff rates from natural landscapes such as prairies and woodlands are quite low due to the absorptive capacity of the soil and the evaporative uptake of lush vegetation. When surface runoff does occur, it often is temporarily stored in adjacent depressions and wetlands. During very wet periods, surface overflow leaves the landscape via small swales and streams, eventually reaching large rivers.

Agricultural development has sometimes increased runoff volumes and rates, primarily due to the drainage of wetlands and the low lying areas and changes in infiltration capacity brought about by agricultural practices, speeding runoff quickly into artificial ditches and channels. Urban development has a dramatic effect on storm water runoff, primarily due to impervious surfaces such as streets, parking lots, and roofs.

The construction of storm sewers and artificial channels further increases the rate and velocity of runoff. Historically, many natural storage areas, swales, drainageways, and wetlands have been completely eliminated by agricultural practices and urban development. This alone can increase downstream flooding by forcing more water into overburdened conveyance systems and floodplain. The obvious effect of uncontrolled agricultural practices and urbanization is a substantial increase in the magnitude and duration of flooding and resultant flood damages. Increased runoff rates caused by agricultural practices and urbanization also tend to destabilize downstream channels, causing streambank erosion which threatens buildings, bridges, farm land, and property.

In addition to identified flooding and streambank erosion problems, agricultural and urban storm water runoff causes severe water quality problems in the form of nonpoint source pollution. Agricultural runoff is often contaminated with sediment, phosphorus, bacteria, and nutrients.

Urban runoff, especially from streets and parking lots, is contaminated with sediment, heavy metals, bacteria, nutrients, and petroleum byproducts. During construction, erosion from uncontrolled development sites contributes massive quantities of sediment. Urban and agricultural runoff pollutants degrade receiving streams and lakes by killing sensitive aquatic life, encouraging non-native invasive vegetation impairing aesthetic conditions, and making recreation unsafe. With sound site planning and the implementation of storm water best management practices, proper operation and maintenance of storm water management facilities, most agricultural and urbanization impacts can be greatly reduced.

D. Concerns

The best management techniques proposed in this plan will not mitigate all flooding and water quality problems caused by runoff from severe storm events. Nor are they intended to improve lands that are inherently unsuitable for development due to poor soils, high water table, or insufficient gradient. But they can help improve water quality and drainage conditions for many sites of average soils and gradient conditions. The techniques proposed can be helpful in dealing with pollution problems of frequently occurring rainfalls of low intensity. Of course, wetlands are high water table lands on which development cannot occur without environmental damage and should be left alone. And too, good basic land design cannot cure all drainage problems.

Fortunately, there are numerous best management techniques available to help improve storm water management for many lands and development within the study area, techniques that may also help reduce flow impacts and pollutant loadings on downstream areas as well as improve drainage characteristics and pollutant reductions on flat lands in various conditions. Farming use over recent years has had an adverse effect on drainage and water quality within the region. Agricultural practices, development for housing, commercial properties, and industrial areas have been developed in many instances without due regard to off-site drainage impacts, or even to drainage effects on the site itself.

Agricultural areas, parking areas, paved roads, rooftops, and compaction of soil coupled with clearing of vegetation from large areas, elimination of drainageways and natural stream flows have created increased runoff and pollutant loads. If these effects continue, existing storm water facilities and natural resources will become increasingly overburdened, further degraded, and unable to handle runoff.

Improvement of local storm water best management techniques, however, guided by creative land design, need to be adopted by the City and individual property owners and users, step by step with any improvements in areawide management systems, if the latter are to work effectively. Areas of particular concern that need to be addressed are:

Agricultural land use practices are systems that alter the natural runoff for legitimate reasons, but increases the rate of runoff, velocity, volumes, and pollutant loads in public drainageways, E-Way, and creeks. Where farming practices are allowed, however, the runoff problem is compounded with field erosion—carrying away soil, pesticides, and fertilizers—which can pollute and silt in drainageways and ecologically sensitive areas.

Residential development has planned and engineered patterns with flat homesites that create the rapid flow of runoff from rooftops, homesites, storm sewer, and impervious paved surfaces that overload the downstream waterways. Residential development imposed on the land without respect to natural drainage patterns causes flooding, erosion, sedimentation, pollutant loads, and destruction to private, public, and ecologically important natural areas.

Commercial land uses, such as shopping centers, business parks, and industrial properties, also contribute to an increased rate of runoff that would not exist in the natural landscape. This is so because these areas are surfaced with impervious paving and storm sewer designed to carry water quickly and effectively away from customer access, parking, loading, and other areas, as well as the buildings, other structures, and valuable open lands on the property. In achieving this legitimate drainage objective, however, large volumes are carried rapidly into public drainageways and streams.

E. Benefits

The following are benefits of the proposed Storm Water Management Plan Best Management Practices (BMPs):

- Improvement of water quality by decreasing pollutant loadings
- Better management of on-site drainage
- Reduction of erosion and sedimentation
- Reduction of downstream flooding
- Enhancement of aesthetic appearance
- Reduction of private and public expenditures on drainage, infiltration and water quality improvements
- Improve groundwater recharge

- Protection of E-Way, wetlands, springs, wildlife habitat and the environment in general from further degradation
- Mitigation of flooding
- Improve natural resources within the E-Way, Yahara River, and downstream lakes
- Property value appreciation
- Improve quality of life in the watershed

The use of most land is highly dependent on adequate drainage. If land resources are to be more wisely managed, protected, or developed, improved measures to control flooding, erosion, sedimentation, and pollutant loads must be put into practice. For much, if not all, agricultural practices and development, there are ways to design the land, improve site drainage, improve water quality, enhance property value, reduce public and private expense, and decrease impact on natural resource areas.

Through improved site and land design, together with local and area wide storm water runoff management, supported by both ordinances, enforcement, and voluntary cooperation at all levels, improved storm water management is achievable.

Section XII.C.-Implementation Benefits and Section X-Recommended Best Management Practices provide additional benefits of implementing storm water management controls. Also, the Dane County Water Quality Plan is the official area-wide Water Quality Management Plan for Dane County.

F. Process of Analysis

The preparation of this plan utilized a process by which to evolve or develop a storm water management plan from a qualitative scientific and technical approach. The following is a brief listing of some of the specific concerns considered during each step in this process.

Data Gathering and Analysis: Certain activities are necessary to start the process. Those included the preparation of base maps on which to record information, field testing and surveys, meetings and discussions with City staff and E-Way Committee to represent interested and affected parties throughout the process. Information gathered, reviewed, analyzed and summarized include: topography, land use, surface and groundwater, infiltration, springs, water quality, water quantity, floodplain, natural resources and wetlands.

Goals and Objectives: Goals are long-term qualitative statements of desirable conditions and ultimate development. Objectives are more specific steps that can be scheduled, budgeted and accomplished as a means to achieve the long-term, goals. Goals and objectives are policy statements as to what the City wants to accomplish with their plan. They provide direction and a basis against which specific alternatives can be evaluated.

Develop Alternatives: Where there is a large amount of undeveloped land within the planning jurisdiction, it may be difficult to project future storm water management needs in relation to proposed layout of streets and structures. One approach is to identify the best use of all land resources at full development, and then refine the storm water impact to develop a plan at the City subdivision, platting and site plan approval process that respects the natural environment and supports the goals, objectives and location criteria prepared in the previous step. Regardless of whether the alternatives are driven by a program of projected future storm water control needs or by the capability of the land, alternatives should express differences in priorities and public policy. The key elements of this phase are to identify preservation and conservation areas, development lands, and the impact of storm water runoff.

Evaluate and Refine Concepts: The objective of this phase, working closely with the City staff and Committee, was to evaluate the implications and trade-offs of each of the basic best management plan alternatives. Some refinement and modification to the goals and objectives resulted during this step. Other policy statements--which we call planning and design guidelines--were developed. These are recommendations that could eventually be incorporated into the zoning and subdivision ordinances. They reflect contemporary environmental planning standards and relate to details that go beyond the storm water management plan. For instance, such guidelines suggest drainage easements and design of storm water detention areas to incorporate aesthetic, ecological, biological as well as hydrologic and hydraulic criteria. Hydrologic criteria include rainfall run-off rates, volumes and velocities that result from rainfall storm events and snow melt.

Elements of Plan

III. ELEMENTS OF PLAN

Requirements for storm water management contained in local ordinances and subdivision regulations (see Appendix F for sample storm water runoff management ordinance) should embody a comprehensive storm water management philosophy. This recommended comprehensive approach includes the following key elements:

- 1) **Provide effective soil erosion and sediment control during construction.** Sediment eroded from construction sites is one of the most important pollutants attributable to urban development. Subdivision codes and ordinances must include effective erosion and sediment control regulations and must be diligently enforced. Effective construction site controls include: avoidance of highly erosive areas such as steep slopes; minimizing the area and time of disturbance; stabilizing disturbed areas with effective erosion control measures as soon as feasible; trapping sediment before it leaves the site; providing routine maintenance and inspection of installed practices; and providing effective enforcement when necessary. Effective soil erosion and sediment control must be in place prior to any land disturbing activities.
- 2) **Minimize impervious surfaces on the development site, consistent with the needs of the project.** This objective can be accomplished by minimizing required street widths, reducing house setbacks, and other creative techniques.
- 3) **Attenuate flows in natural swales, depressions, and waterways.** This objective encourages site designs which, to the extent practical, utilize the existing natural storm water conveyance and storage features to infiltrate runoff and to filter out pollutants. This is in contrast to past "modern" design practices which often fill depressions and replace natural swales with underground sewers and lined channels. Protection of natural drainage features can be accomplished by careful site planning and by planned unit developments (PUDs) which cluster development away from sensitive areas.
- 4) **Infiltrate and filter runoff from impervious surfaces.** This is accomplished by draining rooftops, downspouts, streets, and parking lots onto adjacent lawns, filter strips, swales, and prairie grasses where feasible. This approach maximizes the use of the green areas of a development for storm water management, infiltration, and groundwater recharge. While curb/gutter/storm sewer systems minimize opportunities for contact between impervious runoff and pervious landscaping prior to discharging to streams and natural resource areas, there is a need for curb/gutter/storm sewer pipe systems where natural drainage designs are not feasible and practical.

- 5) **Provide effective storm water detention.** Accepted and researched storm water detention standards have evolved significantly since the late 1980s. Recommended detention storage volumes have increased based on new information on statistical rainfall amounts and evaluations of detention performance. Detention release rates should be based on the natural carrying capacity of downstream channels and floodplains. Release rates also should be controlled for smaller storms such as the 2-year event to reduce the occurrence of downstream channel erosion. Detention should be designed to remove storm water pollutants through improved settling, filtering, and biological uptake. These functions are achieved in basins designed like natural prairies, wetlands, and/or wet ponds.
- 6) **Construct combined storm sewer systems.** Storm sewers are necessary in many developments for effective operation and maintenance and for the purpose of prolonging pavement service life. Storm sewers should be engineered and constructed as combined storm sewer systems. Combined storm sewer systems consist of a combination of storm sewer pipe and grass swale/ditch conveyance systems constructed upland of detention basins systems and receiving water bodies for ultimate storm water runoff volume and pollutant loading reductions by maximizing infiltration. Discharging storm sewer pipe systems directly to receiving water bodies, such as wetlands, creeks, streams, and lakes, should be discouraged.
- 7) **Promote cost-effective non-structural control Best Management Practices (BMPs),** such as cluster developments, street sweeping, less fertilizers, homeowner source pretreatment systems, ordinances, land use controls, catch basin sumps, agricultural land management practices, no till farming, public education and information.

Goals and Objectives

IV. GOALS AND OBJECTIVES

For the sake of definition, goals are the broadest category used in this plan. They set the over-all aims of the Nine Springs Neighborhood Storm Water Management Plan. Contained below are several key goals for the Nine Springs Neighborhood Area proposed development:

- Goal 1: Mitigate to the extent most practical existing drainage concerns and problems, and reduce post-development storm water runoff peaks and volume to pre-development levels;
- Goal 2: Protect and restore impaired uses of existing natural and water resources, including lakes, streams, woods, springs, floodplain, and wetlands, from determinate and unnecessary modification so that their beneficial functions are maintained and improved, and long-term public expenditures and damages are minimized;
- Goal 3: Reduce or mitigate the environmentally detrimental effects of existing and future storm water runoff in order to improve and maintain water quality and protect water-related environments;
- Goal 4: Provide for the short and long-term maintenance of natural and man-made drainageways and storage facilities in new and existing developments;
- Goal 5: Develop a comprehensive hydrologic, hydraulic, demographic, and topographic data base using the best available and most appropriate technology to manage the storm water, flood, and water quality data needs of the program;
- Goal 6: Establish uniform, minimum, storm water management regulations while recognizing and coordinating with those storm water programs effectively operating within the County, State and adjacent municipalities;
- Goal 7: Promote the awareness, education, and understanding of storm water management issues by the developer and the layperson through an ongoing public information program;
- Goal 8: Coordinate with surrounding communities to ensure minimal negative impacts of inter-municipal storm water runoff flows and pollutant loadings.
- Goal 9: Coordinate phased construction of recommended storm water management best management practices (BMPs) in accordance with Nine Springs Neighborhood Plan proposed phased development sequence.

Natural Resource Cover Mapping

V. NATURAL RESOURCE COVER MAPPING

See Appendix A.

Infiltration/Hydrogeology

VI. INFILTRATION/HYDROGEOLOGY

A. Introduction

The infiltration testing program was undertaken to identify the existing rates of infiltration at different locations within the drainage area of the Nine-Springs Neighborhood Planning Area (planning area). Infiltration has been identified by the City and others as being a key component in the overall management of the water balance within the planning area. In recognition of the importance of infiltration, this storm water management plan was developed to utilize the best available designs and management practices in order to: (1) reduce storm flow volumes; (2) encourage infiltration, and; (3) reduce pollutant loading, in order to; (4) minimize impact to the wetlands, springs and other natural features.

To best meet these objectives, development of the storm water management plan has followed an integrated approach where both surface, and groundwater, management methods have been considered throughout, with infiltration incorporated as the common link between the two. Specifically, the plan was developed to ensure maximum infiltration and subsequent recharge to the shallow groundwater in order to maintain spring flow and groundwater discharge to the wetlands, while limiting the potential negative impacts of storm water on the wetlands.

Within the planning area, the interrelationship between infiltration, groundwater recharge, and discharge to the wetlands and springs is poorly understood at present, but has been the topic of much interest among local investigators. Much of this interest has been summarized, and further generated, by the 1996 Water Resources Management Practicum (Institute of Environmental Studies, 1996) led by Professor Ken Potter at the University of Wisconsin. The Practicum identified the need to protect wetlands by ensuring that spring flow was of adequate quantity and quality through the coordinated use of storm water and groundwater recharge management. The study recommended that sufficient infiltration and recharge occur to ensure adequate spring flow and discharge to maintain the wetlands.

Infiltration. Infiltration is quantified as the volume of water that crosses the soil surface to enter the unsaturated (vadose) zone above the water table. The relationship between infiltration and groundwater recharge is given by the soil-water balance equation (Stephens et al, 1996):

$$R = I - E - T - \Delta S$$

where

R	=	groundwater recharge
I	=	infiltration
E	=	evaporation
T	=	transpiration
ΔS	=	net change in soil-water storage

From this relationship, it is apparent that maximum groundwater recharge occurs when infiltration is high and evapotranspiration is low. Water stored within the soil zone may move back up to the surface through evapotranspiration, or downward to recharge the groundwater. The deeper within the profile that the water is stored, the greater the likelihood that the water temporarily stored within the soil will move downward and recharge the groundwater.

The amount of water available for infiltration depends on the amount of precipitation that is available to enter the soil profile, according to the following relationship between precipitation, runoff and infiltration:

$$\text{infiltration} = \text{precipitation} - \text{runoff} - \text{surface interception}$$

Surface interception is the amount of precipitation that evaporates or is otherwise intercepted before reaching the land surface. This relationship forms the basis for the storm water and surface water computer models.

The rate of infiltration is controlled by the physical characteristics of the soil as well as the availability of water at the land surface. Under low application rates, the rate of infiltration is controlled by the rate of application. Such infiltration is classified as "flux-controlled infiltration." Under higher application rate, where the rainfall or snowmelt rate exceeds the permeability of the soil, the rate of infiltration is controlled by the permeability of the soil. Under such "profile-controlled infiltration," ponding and runoff can develop at the land surface.

For flux-controlled infiltration in the absence of ponding or runoff, the infiltration rate is equal to the rainfall rate minus any loss to evapotranspiration. Flux controlled infiltration occurs wherever the rate of application is less than the saturated hydraulic conductivity of the soils, such as during light rainfall. For profile-controlled infiltration, however, the infiltration rate and the potential for groundwater recharge are greater for soils that are highly permeable than for soils with low permeability.

Profile-controlled infiltration rates are not constant, but vary according to the wetness of the soil and the length of infiltration, following the relationship proposed by Philip (1969):

$$I = \frac{1}{2}st^{-1/2} + K$$

where:

I	=	infiltration
s	=	sorptivity, a measure of the capillary potential of the soil.
t	=	time
K	=	saturated hydraulic conductivity (permeability)

This relationship shows that the rate of profile-controlled infiltration is greatest during the early stages of a given infiltration event, and for initially dry soils. As infiltration proceeds, the term $\frac{1}{2}st^{-1/2}$ decreases toward zero, and the infiltration rate approaches a value equal to the permeability of the soil. Sorptivity, a measure of the capillary component of infiltration, is a function of the moisture content and grain size of the soil. Sorptivity, and consequently, the term $\frac{1}{2}st^{-1/2}$, are greatest for dry fine-grained soils, and least for moist, coarse sands and gravels. Although some surface-water models ignore the temporal nature of infiltration rates, the more sophisticated models use the above relationship for simulating the generation of ponding and runoff at the land surface.

The above infiltration relationship holds true for porous media with primary, intergranular porosity. Soils with secondary and macropore porosity typically have very low values for sorptivity, and the infiltration rate at virtually all times is nearly constant at a value approaching the saturated hydraulic conductivity of the porous media-macropore ensemble.

The contribution of local recharge to spring flow and groundwater discharge into the wetlands is not fully understood at present. One conceptual model of the interaction between localized recharge and spring flow has been proposed by the Practicum Report (Institute of Environmental Studies, 1996), wherein the springs are recharged by shallow, confined groundwater flowing within permeable horizons in the glacial deposits at shallow depths. Pursuant to the Practicum Report, the springs occur where the overlying low-permeable clay loam is thin or absent, and the confined shallow groundwater upwells and discharges to the land surface. Recent discussion with the UW and WGNHS investigators suggests that this conceptual model may be an oversimplification of the actual conditions, and that some of the spring flow might be supplied by deeper groundwater originating from areas outside of the planning area. The persistence of spring flow during periods of low precipitation lends support to this hypothesis. Dr. Jean Bahr at the University is conducting a tracer study to determine the possible sources of water at the springs. This study is currently underway, and the results are not yet available. Dr. Bahr is also exploring the use of a finer-detailed computer groundwater model to better define the

contributing recharge areas for the groundwater discharged at the springs. Potential recharge areas had previously been identified by the Practicum using the Dane County Regional Groundwater Model and reverse particle tracking. However, the WGNHS and UW staff investigators acknowledge that the coarse grid used for the model, and the sparsity of data, makes these results questionable. The finer-detailed model should provide a more reasonable depiction of the contributing recharge areas. The results of these two studies should be reviewed to better determine the importance of local recharge areas. The results of these ongoing studies and our site-specific infiltration rate testing program confirms that maintaining the optimal rates of infiltration is important to the overall water balance of the system, and should be encouraged wherever practical. The present storm water management plan has been developed using every reasonable management practice available in order to ensure optimal infiltration rates. This necessitated the determination of actual, field-scale infiltration rates for different topographic, vegetation and land-use settings.

B. Methods

A site-specific testing program was undertaken to determine the ambient infiltration rates within the planning area. This program was designed to determine the field-scale, vertical permeability of the surface and near-surface soils at representative locations and settings throughout the planning area, in order to provide site-specific input parameters for the storm water computer models, and to help refine the conceptual models of coupled infiltration, groundwater recharge, and spring flow.

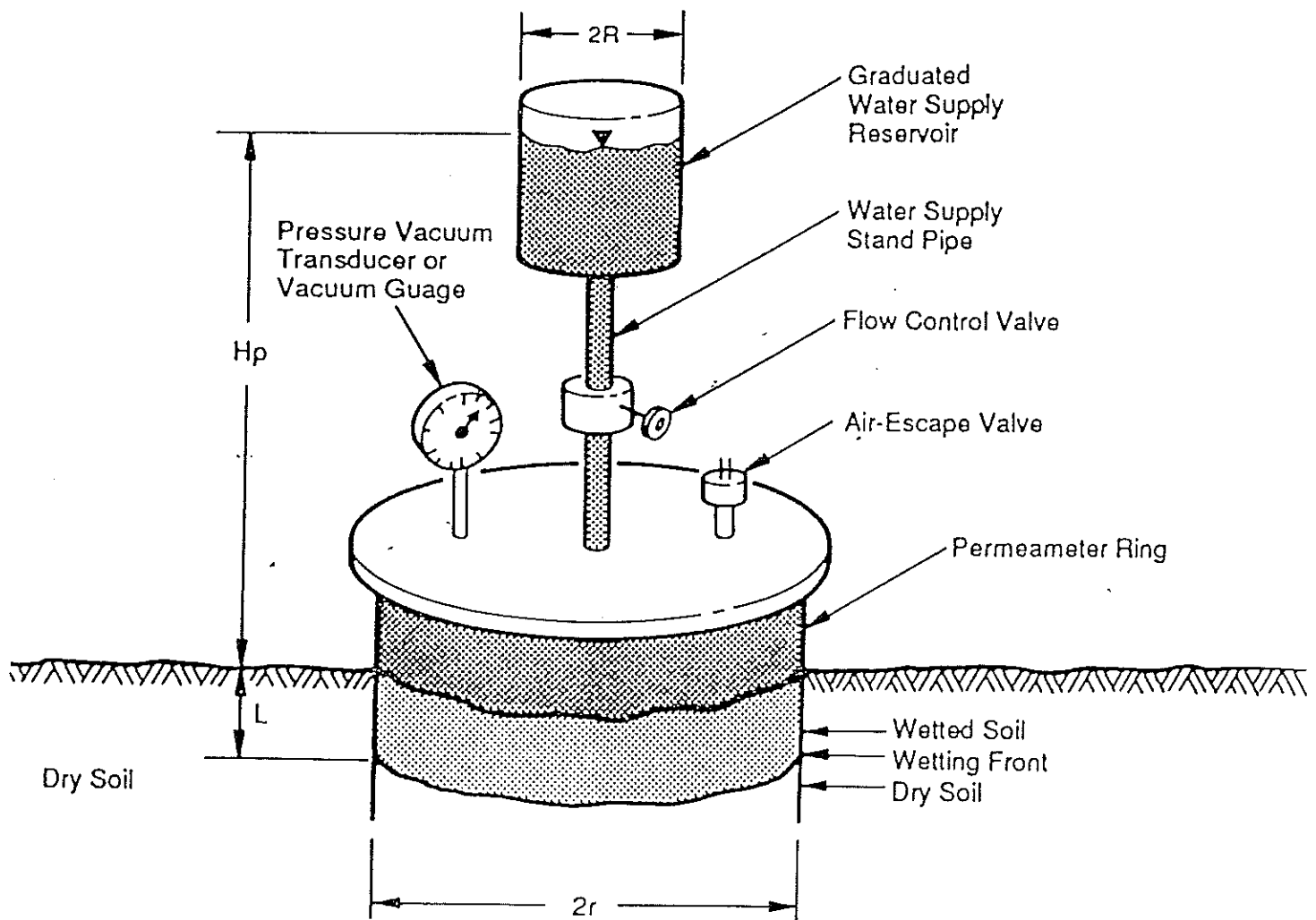
Air-Entry Permeameter. Air-entry permeameter testing was selected as being the most appropriate method for this study. The air-entry permeameter was first designed by Herman Bouwer of the United States Department of Agriculture for the rapid field measurement of the vertical, field-saturated hydraulic conductivity (permeability) of materials above the water table. Air-entry permeameters have been successfully used for a variety of applications under different field conditions. A body of literature exists describing the theory and use of these permeameters, including Bouwer, 1966; Knight and Haile, 1984; Amoozegar and Warrick, 1986; Stephens, et al, 1988; ASTM D-5126, 1992; Havlena and Stephens, 1992; Stephens, 1996, and; Stephens, et al, 1996. These references support the assertion that air-entry permeameter testing is the only currently-available field method that accounts for capillary effects and the imposed hydraulic gradient while measuring vertical, field-saturated hydraulic conductivity (permeability), to provide accurate results under a variety of conditions.

The permeameter consists of an open-ended metal cylinder (ring), usually one foot in diameter and about one foot high, that is driven vertically into the soil (Figure 5). A transparent, polycarbonate top plate with a valve and a vacuum gauge, and a water-supply reservoir are mounted onto the top of the ring to supply, and control, the infiltrating water.

The testing is conducted in two steps: (1) infiltration and (2) drainage. During infiltration, the valve at the bottom of the water-supply reservoir is opened, and water is allowed to infiltrate into the soil that is enclosed within the permeameter ring. The rate of decline of the water level within the graduated water-supply reservoir is measured. Once an approximately-steady flow rate is achieved, the valve is closed to stop infiltration, and the drainage portion of the test is started. As the water within the soil moves vertically downward under gravity it creates a slight vacuum within the closed upper portion of the permeameter. The vacuum supports the water within the soil pores (much like an inverted drinking glass will hold water under a vacuum) until the air-entry pressure of the soil is reached. At that point, the larger soil pores began to drain, and air moves upward through the larger pores and accumulates in the top of the permeameter ring. The vacuum at which this happens indicates the air-entry pressure of the soil, which is used as a surrogate for the so-called "wetting-front pressure head" in a Green-Ampt formulation of the infiltration equation. The solution equation incorporates the rate of decline of water in the water-supply reservoir, the air-entry pressure, as well as the depth of infiltration measured after completion of the test.

Although the air-entry permeameter was not specifically designed for testing the permeability of the soil matrix for soils containing macropores, these permeameters will provide reasonable estimates for the effective permeability of the soil and macropore ensemble. Values for the permeability of macro-porous soils determined using an air-entry permeameter are dominated by the hydraulic conductivity of the macropores. However, because the depth of infiltration within the soil matrix is measured at the end of each test, rather than the depth of infiltration within the macropores, the resulting values for permeability are likely to be somewhat less than actual.

Site Selection. A total of 12 testing sites were selected (Appendix B - Map #2). Selection of these sites was based on their location within the basin, current land use and agricultural practices, soil type, vegetation and topography. Selection of testing locations was also constrained by our ability to access properties during the testing program. Emphasis was given to testing soils from the Plano-Ringwood-Griswold soil association, which is the dominant soil association within the planning area.



Air-entry permeameter. (From Havlena and Stephens, 1991. With permission.)

FIGURE 5

Individual testing locations were selected from cultivated and non-cultivated fields underlain by the identified soil types in order to compare infiltration rates for the different land-use practices. Table 4 lists the testing locations and their individual characteristics.

A total of 19 individual tests were successfully completed during the infiltration testing program. Nine tests were completed within cultivated soybean and/or cornfields, two within treed upland sites at McGaw Park, four within restored prairie, three within the park lawn at McGaw Park, and one completed within a cultivated pasture.

Of the 19 successful tests, nine were conducted at the land surface, three between the land surface and a depth of one foot, and seven between one and two feet deep. Tests were conducted at more than one depth at six of the test sites.

Testing Procedures. The air-entry permeameter testing was conducted according to the standard methods and procedures described in Bouwer, 1966, ASTM D-5126, Stephens et al, 1988, Havlena and Stephens, 1992, Stephens et al, 1996, and Stephens, 1996. The permeameter used for the testing was specially fabricated by Daniel B Stephens & Associates, Inc., and consisted of an aluminum permeameter ring 11.5 inches inside diameter by 10.2 inches high, a top plate, several different diameter water-supply reservoirs, and lengths of clear PVC standpipe. Madison city tap water was used for all testing.

The surface of each site was prepared prior to testing. For tests at the land surface, vegetation was trimmed to about 1 inch above the ground, and debris and litter were removed in order to prevent clogging of the valves during testing. For tests conducted below ground level, the surface of the test horizon was prepared by carefully scraping the soil to approximately level with the edge of a flat trowel. Trial and error has shown this to be the best method for preserving soil texture and reducing potential disturbance to the soil. Once the test surface was properly prepared, the permeameter ring was driven into the ground using a hand-operated fence-post driver until about 2 to 6 inches of ring remained above the surface. The depth that the permeameter ring was buried was then measured, the top plate secured with C-clamps, and the water-supply reservoir and clear acrylic standpipe attached to the top plate. Measurements were taken of the height of the zero mark on the graduated water-supply reservoir, the height of the vacuum gauge, and the temperature of the soil and the water. The zero mark on the graduated water-supply reservoir was typically set at about 30 inches, providing a hydrostatic head ranging from 30 inches to about 42 inches of water above the test surface. The vacuum gauge was typically set at about 12 inches above the level of the test surface.

Table 4. Air-Entry Permeameter Test Locations and Characteristics

Test Designation	Property	Approximate Latitude	Approximate Longitude	Setting	USDA Soil Series	Test Depth Interval (in)
1	McGaw Park #1	42.59.894	89.24.378	Sparsely Forested	GwC	6" to 10.8"
2	WARF #1	43.00.893	89.23.803	Cornfield	DnB	3" to 6.7"
3	WARF #2	43.00.827	89.23.904	Cornfield	RnB	0" to 6.3"
4	WARF #2	43.00.827	89.23.904	Cornfield	RnB	20" to 25.5"
5	Tom Holmes	43.00.533	89.23.522	Soybean/Cornfield	GwC	0" to 4.9"
6	Tom Holmes	43.00.533	89.23.522	Soybean/Cornfield	GwC	20" to 22.9"
7	DNR #1	43.00.366	89.24.361	Restored Prairie/Formerly Cultivated	TrB	0" to 7.7"
8	DNR #1	43.00.366	89.24.361	Restored Prairie/Formerly Cultivated	TrB	16" to 20"
9	DNR #2	43.00.267	89.24.250	Restored Prairie/Formerly Cultivated	PnB	0" to 5.8"
10	DNR #2	43.00.267	89.24.250	Restored Prairie/Formerly Cultivated	PnB	17" to 22"
11	Marc Jones #1	43.00.432	89.23.827	Soybean Field	RnB	0" to 4.7"
12	Marc Jones #1	43.00.432	89.23.827	Soybean Field	RnB	10.5" to 14.7"
13	Marc Jones #1	43.00.432	89.23.827	Soybean Field	RnB	23" to 26.1"
14	Marc Jones #2	43.00.455	89.23.785	Grass Pasture	RnB	22" to 24.5"
15	McGaw Park #2	42.59.994	89.24.325	Forested	PnB	0" to 7.7"
16	James Holmes	43.00.971	89.23.603	Soybean/Cornfield	DnB	0" to 0.84"
17	McGaw Park #3	42.59.866	89.24.348	Grassy Area in Park	PnB	0" to 6.0"
18	McGaw Park #3	42.59.866	89.24.348	Grassy Area in Park	PnB	20" to 21.8"
19	McGaw Park #3a	42.59.860	89.24.348	Grassy Area in Park	PnB	0" to 5.5"

Once the permeameter was installed and the dimensions measured, the water-supply reservoir was filled with water, the flow control valve opened only partway to minimize disturbance to the soil surface, and the air-escape valve opened to allow air to exit as the water filled the headspace between the soil surface and the permeameter top plate. Once the headspace was completely filled with water, the flow-control valve was fully opened, the air-escape valve closed, the water level topped off, and the infiltration testing begun. The level of water within the graduated water-supply reservoir was measured every five or ten seconds, depending on the flow rate and the number of personnel in the field team. The water-supply reservoir was replenished as necessary; some tests requiring more than others depending on the presence of large macropores.

Infiltration was allowed to continue until an approximately-steady rate of water-level decline was obtained in the water-supply reservoir. The flow control valve was then shut off, and the control valve to the vacuum gauge opened to conduct the drainage portion of the test. In order to limit any further infiltration and ensure a sharp wetting front, the residual positive hydraulic head was dissipated by briefly opening the air-escape valve. For most tests there was an almost immediate increase in vacuum to a gauge value of about 17 inches of water vacuum. The location and character of all bubble streams coming up through the soil surface were observed through the clear polycarbonate top plate. All bubble streams were observed to originate from the interior of the ring, none were seen to come from along the inside wall of the ring (which would indicate improper installation of the ring and invalidate the test). Most of the bubble streams were moderate-to-large sized, and persistent, indicating that large-diameter pores were draining first.

Once the air-entry pressure was reached and the location and character of the bubble stream(s) noted, the C-clamps were removed, the top plate lifted off of the permeameter ring, and the free water within the ring was removed. At this point, the character of the soil surface was observed and the distance between the soil surface and the top of the ring measured as a check for soil swelling. The depth to the wetting front was visually determined by hand-excavating through the tested soil within the permeameter ring until the soil appeared similar to un-wetted soil. The depth at which the amount of moisture within the soil beneath the permeameter ring appeared to be similar to that of the soil outside of the ring was recorded as the depth of the wetting front.

For several tests, a hand auger was subsequently used to determine the lithology and character of the soil materials beneath the ring. The soil type, texture, structure, and other characteristics were noted.

Hand-augered soil samples were also collected at one-foot intervals at two sites for subsequent analysis of soil chloride concentrations. We intended these results to be used for a chloride mass-balance analysis for determining in-situ recharge rates. However, this methods assumes uniform, "piston" displacement type infiltration where the infiltrating water flushes the existing water from the soil pores as it infiltrates, and the depth of infiltration is uniform. The results of the infiltration testing show that these conditions are not present, and use of the chloride mass-balance methods for determining recharge was deemed to be inappropriate for the macro-porous soils found within the planning area.

At the end of each day's field testing, all data were entered into an Excel spreadsheet that had been developed for the analyses. Copies of the spreadsheet for each test, along with graphs that show the rate of decline in the water-supply reservoir for each test are included in Appendix C.

C. Results

- An Excel spreadsheet was set up to analyze the raw field data using the solution equation found in Bouwer (Bouwer, 1966), which incorporates a factor of two in the solution in order to account for field saturation (satiation) and the effects of air entrapment during infiltration. The viscosity of the infiltrating water was considered in the analyses, using the measured water temperatures.

The results are presented in Table 5, along with observations made during each individual test. Table 5 shows a wide range of values for permeability, ranging from a low of 0.00076 inches per hour, to a high of 32.6 inches per hour, with an average value of 13.5 inches per hour. The field-determined values appear to be insensitive to soil type and location within the basin, but do appear to be sensitive to depth and land use. At all sites where multiple depths were tested, there was a distinct decrease in permeability with depth. This appears to be most pronounced for the tests conducted within cultivated soybean and corn fields, where permeability typically decreases from greater than 10 inches per hour at the land surface to 3.7 or less at depths between 16 to 23 inches. The decrease in permeability with depth was less pronounced at the prairie and grass sites, where the permeability below one foot deep remained consistently at, or greater than, 6 inches per hour.

The permeability determined for all but two of the nine tests conducted at the land surface was greater than nine inches per hour, ranging from 9.1 to 32.6 inches per hour, with an average of 15 inches per hour. These values are considerably higher than the estimates (0.63 to 2 inches per hour) listed in the Dane County Soil Survey (USDA, 1978).

Table 5. Summary of Infiltration Testing Results

Property	Setting	Test Designation	Test Depth Interval (in)	Permeability			Air-Entry Pressure (cm water)	Observations
				cm/sec	in/hour	USDA Estimated Permeability (in/hour)		
NR #1	Restored Prairie/Formerly Cultivated	7	0" to 7.7"	8.6E-03	12.2	0.63 - 2.0	0	many macropores and rootlets; could hear water draining into macropores
		8	16" to 20"	4.9E-03	6.9	0.63 - 2.0	-0.2	same location as test #7; many macropores and rootlets; could hear water draining into macropores
NR #2	Restored Prairie/Formerly Cultivated	9	0" to 5.8"	8.4E-03	11.9	0.63 - 2.0	0	macropores and rootlets; big bubbles from one location within ring
		10	17" to 22"	4.3E-03	6.0	0.63 - 2.0	0	same location as test #9; many macropores and rootlets; small to medium bubbles from at least 4 locations within ring
James Holmes	Soybean/Cornfield	16	0" to 0.84"	5.4E-07	0.00076	0.63 - 2.0	-60.4	no sign of macropores on surface, and very little sign at depth; erosional features along northern edge of the sloping field
Arc Jones #1	Soybean Field	11	0" to 4.7"	2.3E-02	32.6	0.63 - 2.0	0	large macropores, bubbles and nightcrawlers
		12	10.5" to 14.7"	1.8E-02	26.0	0.63 - 2.0	0	same location as test #11; large macropores, bubbles and nightcrawlers
		13	23" to 28.1"	2.6E-03	3.7	0.63 - 2.0	-17.5	same location as tests #11 and 12; large macropores, bubbles and nightcrawlers
Mac Jones #2	Grass Pasture	14	22" to 24.5"	5.8E-03	8.2	0.63 - 2.0	0	macropores and earthworms; could hear and see water draining down macropores
McGaw Park #1	Sparsely Forested	1	6" to 10.8"	4.6E-03	6.5	0.63 - 2.0	0	macropores and rootlets
McGaw Park #2	Forested	15	0" to 7.7"	9.3E-04	1.3	0.63 - 2.0	-3.8	many, mostly horizontal, roots and rootlets from maple trees and grasses
cGaw Park #3	Grassy Area in Park	17	0" to 6.0"	8.4E-03	9.1	-	-23.6	ring driven through sod and topsoil layer into base-course fill gravels; many earthworms within topsoil
		18	20" to 21.8"	8.0E-03	8.5	0.63 - 2.0	0	number of large macropores and earthworms; water coming up from around bottom of ring during late-stage infiltration; used early-time infiltration data for analysis
McGaw Park #3a	Grassy Area in Park	19	0" to 5.5"	8.6E-03	9.3	-	0	ring inserted in top 3.3 inches; bottomed at top of fill gravel; results use early-time data; late-time data questionable cause welling from extended well beyond bottom of ring and spread several inches laterally on top of gravel; could hear "gubing" from around outside of ring during drainage
Tom Holmes	Soybean/Cornfield	5	0" to 4.9"	1.4E-02	19.8	0.63 - 2.0	0	large bubbles from 2 roots/macropores
		6	20" to 22.9"	8.3E-04	1.2	0.63 - 2.0	-12.9	same location as test #5; surface 1cm disturbed from permeameter installation; small bubbles
WARF #1	Cornfield	2	3" to 6.7"	5.2E-03	7.4	0.63 - 2.0	0	fewer macropores than test #1
ARF #2	Cornfield	3	0" to 6.3"	7.3E-03	10.4	0.63 - 2.0	-2.6	desiccation cracks on surface; moist along macropores to 20 in deep
		4	20" to 25.5"	1.3E-03	1.9	0.63 - 2.0	-3.1	same location as test #3; fewer macropores than test #3; some rootlets at 23"

The permeability of the soils between one foot and two feet was significantly greater than the USDA estimates only at the test sites within prairie or grassy areas, ranging from 6 to 8.5 inches per hour. This contrasts with a range of 1.2 to 3.7 inches per hour at similar depths under soybean and corn fields. Based on field evidence, it appears that the greater-than-expected values for permeability are due to the presence of macropores and secondary porosity within the soil profile, as discussed in the next section.

Of the two surface tests that did not produce results significantly greater than the USDA estimates (USDA, 1978), one was clearly anomalous. Test number 16, conducted on the James Holmes property in the southeast corner of Syene and Clayton Roads, produced an exceptionally low value for permeability: 0.00076 inches per hour, less than one 800th of the USDA value. The field-measured value appears to be appropriate for a clay or clay loam without any macropores or secondary porosity. Field observations confirm the clay-rich nature of this soil and the general lack of macropores and secondary porosity.

The other surface test with a permeability value not greater than the USDA estimates was conducted in the forested portion of McGaw Park. The value determined by this test was 1.3 inches per hour, within the range of USDA estimates. Field observations of the soil at this location showed a general lack of macropores and secondary porosity.

D. Discussion and Conclusions

The results and observations show that infiltration rates near the land surface are greater than those published by the USDA (USDA, 1978). The infiltration capacity of these soils at typical ambient moisture contents should be sufficient to allow considerable infiltration into the upper soil layer. For most low-to-moderate rainfall events, there should be sufficient permeability and storage within the upper soils to prevent the generation of significant runoff. The rainfall will infiltrate rapidly into the subsurface, where it is available for subsequent consumption by plants, or downward percolation toward the water table.

The infiltration test results and observations offer strong evidence for the importance of macropores on infiltration rates. The tests with the highest values for permeability were those conducted in soils that were observed to contain many, large-diameter, continuous macropores. Virtually all of these tests quickly reached rapid steady state flow rates, and had air-entry pressures at or very close to zero, offering strong indication of the importance of macropores to infiltration. The macropores were visually observed during ring installation and exhumation. Evidence of their occurrence and impact on infiltration is given by the much higher-than

expected flow rates, the low values for air-entry pressure (larger pores drain at lower vacuums; the largest draining at near-zero vacuum), the size of the air bubbles observed during drainage testing, and gurgling sounds heard during drainage.

The presence of large earthworms and nightcrawlers at most of the test sites suggests that the macropores are associated with worm burrows. Although a number of roots and rootlets were also observed during the testing, virtually all of the largest diameter, and vertically straight, smooth, and continuous macropores either did not have roots within them, or were observed to contain earthworms. Virtually all roots and rootlets were observed to be consistently smaller in diameter than the macropores, and were not vertically straight and continuous.

Macropores provide for rapid infiltration and increased storage of water in the subsurface, which likely enhances recharge of the shallow groundwater. Where macropores exist and are continuous to depth, they provide a ready pathway for infiltrating water to move into the underlying shallow groundwater (Figure 6). There appears to be a strong relationship between depth and permeability. The frequency and size of macropores and rootlets appear to both diminish with depth, as does the soil permeability. This is most pronounced at the cultivated sites where the permeability drops by about an order of magnitude between the soil surface and 1 ½ to 2 feet deep. The observed permeability at about a foot and a half at the prairie sites was several times greater than the permeability at similar depths in cultivated fields. The soil profile within prairie grass sites was observed to be less dense, with more macropores and rootlets at depths below the plow depth than the cultivated soils.

These apparently-worm-created macropores likely persist to depths greater than 30 inches. Evidence for this is provided by direct observation of macropores, earthworms, and rapid drainage at depths to 30 inches. It is very important to limit the application of typical lawn chemicals due to the fact that they would be detrimental to worm-created macropores.

These observations suggest that it should be possible to achieve consistently high infiltration and shallow groundwater recharge rates with minimal maintenance by encouraging deep, continuous, large-diameter macropores through the use of prairie and grasses infiltration areas. Agricultural practices should also be reviewed for their impact on macropores. Practices such as no-till, slot-mulching, and limiting the use of pesticides that impact the number and activity of earthworms should be further explored. Such careful management should minimize storm water runoff and provide maximum groundwater recharge to maintain springflow and reduce negative impacts to the wetlands.

COMPARATIVE DEPTH OF INFILTRATION

PLANO-RINGWOOD-GRISWOLD SOIL ASSOCIATION

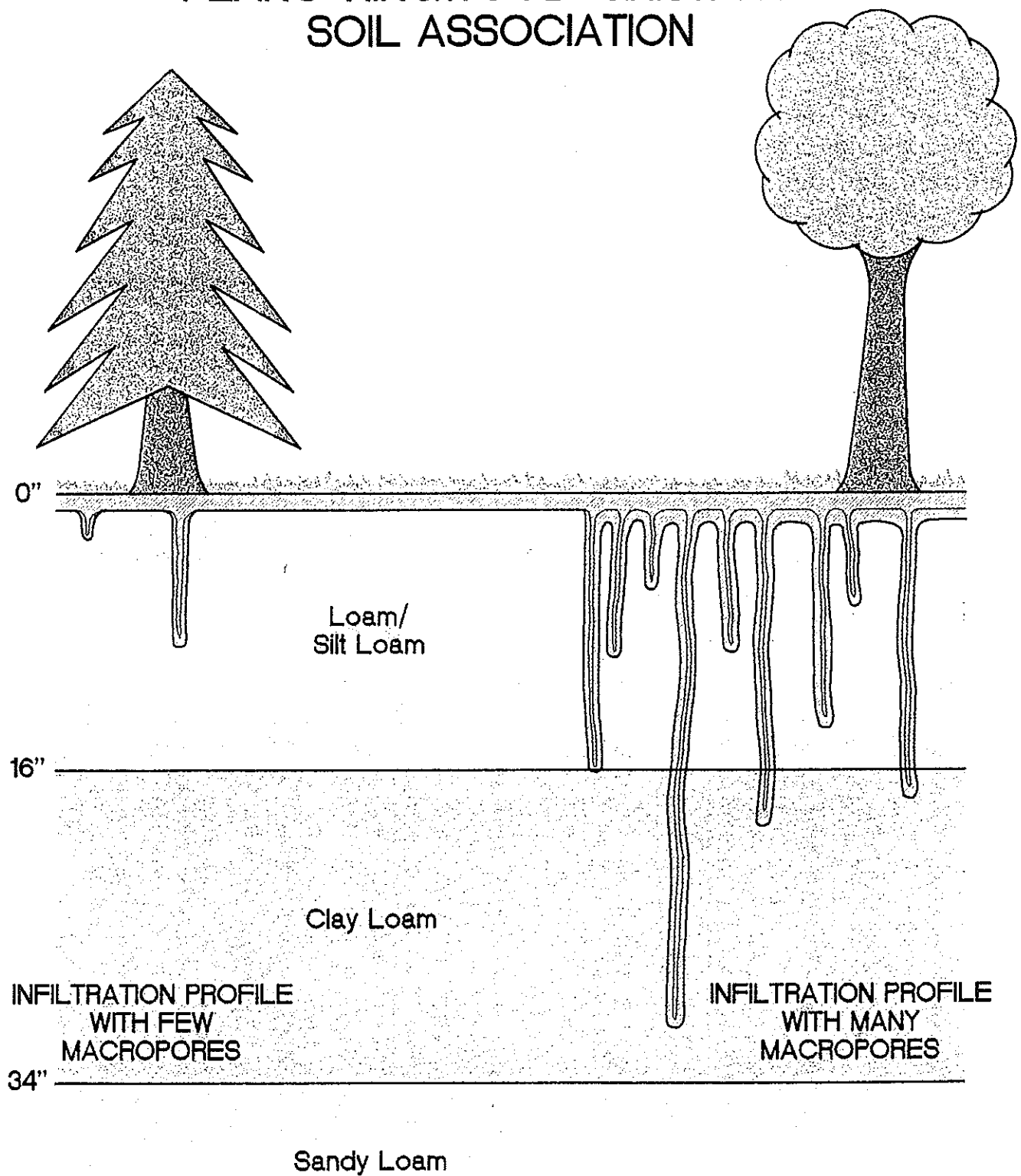
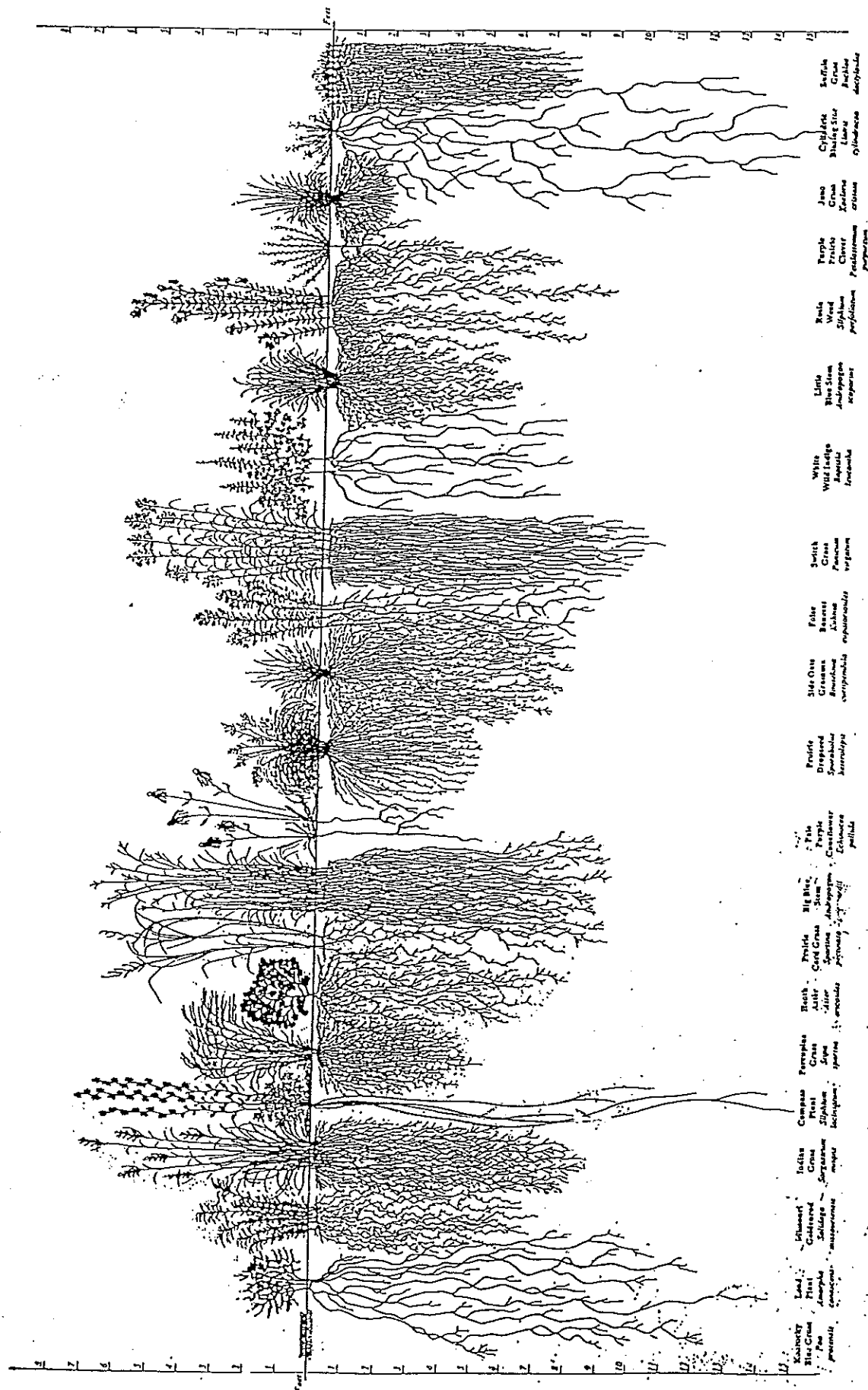


FIGURE 6



Root Systems of Prairie Plants

Storm Water Quantity

VII. STORM WATER QUANTITY

A. General

In order to provide a useful document that addresses all aspects of storm water management planning, an analysis of the existing system and of the proposed future system must be accomplished. The system analysis is a technical investigation of the land use, storm sewers, overland drainage, water quality, wetlands, lakes, ponds, streams, channels, and drainageways. The analysis was accomplished using the best available hydrologic and hydraulic modeling methodologies for storm water management water quantity which includes pipe flows, overland flows, drainageway flows, and detention pond storage of storm water runoff.

In the ideal design solution, most of the precipitation falling on a given drainage area would be absorbed or retained on-site. After development, the quantity and rate of water leaving the site should not exceed undeveloped conditions. The same principle would apply to nutrients and pollutants to avoid impacting the natural and water resources of the watershed. Unfortunately, the only true way to achieve this is by not developing or farming at all. By developing some areas, farmed erosion would be reduced with installation of wet detention basins, constructed wetlands, lawn grass, and prairie grasses. Even when the pollutant loads and runoff rates could be matched by undeveloped conditions, the wildlife habitat, ecology and aquatic biota is displaced by human activities and impervious surfaces. Therefore, the ideal solution is to achieve a balance between storm water quality and quantity to the extent most practical.

The storm water management system facilities discussed in this plan consist of interconnected open channels, drainageways, ditches, prairie grass vegetation, pipes, culverts, bridges, ponds, and wetlands. The analysis of the storm water management system involves the following aspects:

- Division of the watershed into major subwatersheds and subareas based on contour maps, grading plans, and natural topographic features.
- Determine the amount of runoff anticipated under existing land use conditions and ultimate future land use conditions.
- Select a method of conveying that runoff.
- Delineate conveyance and detention areas for storm water runoff volume; storage, sediment, and pollutant treatment.

- Identification of vegetation cover types, woods, wetlands and high priority water bodies.
- Develop measures to maintain and enhance the groundwater recharge and water quality in the watershed.

B. Watersheds

The watershed was divided into eight major subwatersheds as shown on maps in Appendix B - Map #3. The subwatersheds are entitled "A" through "H". *Please note that the Nine Springs Neighborhood Storm Water Management Planning Area is much larger than the proposed Nine Springs Neighborhood Land Planning Area.* This methodology was utilized to define hydrologic and hydraulic effects. Hydrologic effects are influenced by entrance of tributary drainageways, watershed shape, land use, valley slope changes, homogeneity of the runoff curve number, and existing or proposed impoundment structures (low areas and detention basins).

Two planning periods were chosen to assess the storm water runoff hydrology within each subwatershed. Land use characteristics were projected for both planning periods. The planning periods used correspond to the Nine Springs Neighborhood Land Use Plan prepared by the Discovery Group, February 19, 1997, and include present land use (1997) and future projected land use analysis periods.

C. Hydrology/Hydraulics

Storm water runoff is defined as that portion of precipitation which flows over the ground surface during, and for a short period of time after, a storm event. The quantity of runoff is dependent on the intensity of the storm event, the initial moisture condition and infiltration capacity of the soil, the amount of antecedent rainfall, the length of the storm event, the type of surface the rain falls on, and the slope of the surface.

The intensity of a storm event is commonly associated with its period of return which designates the average period of years during which a storm of a certain magnitude has a probability of occurring. The degree of protection is determined by selecting a return storm event interval to be used as the basis for design. The storm events used in the plan include a 10-year frequency storm event for storm sewer design and a 100-year frequency storm event for overland drainage and detention pond design. A ten-year frequency storm has a 10 percent probability of occurring or being exceeded in any given year, and a 100-year frequency storm has a 1 percent probability of occurring or being exceeded in any given year.

Based on historical data prepared by U.S. Weather Bureau Technical Paper No. 40 charts, a 10-year frequency storm consists of 4.2 inches of rainfall in 24 hours while a 100-year frequency storm consists of 6.0 inches of rainfall in 24 hours.

Complete protection against large, infrequent storms with return intervals greater than 100 years are economically justified only for large, important flood control projects. For most developing areas within the watershed, the cost of construction of a large capacity storm water management system is much greater than the amount of property damage that would result from flooding caused by a storm event which a smaller capacity system could not accommodate.

The excess storm water runoff caused by storms greater than the design storm will be accommodated by ponding in low street areas and/or overflow through overland drainage routes. This short-term flooding and overland drainage will minimize much of the damage to property which would occur if those facilities were not provided. *Therefore, we recommend that provisions be made to provide or preserve overland drainage routes for emergency overflows.*

A number of methods are available to determine the expected maximum rate of runoff from a known area for a certain design storm and a certain soil moisture condition. These methods include the rational method, the USDA-Soil Conservation Service TR-20 and TR-55 models, and the U.S. Army Corps of Engineers HEC-1 model. The design methodologies presented in this storm water management plan for estimating runoff (hydrology) and system hydraulics are based on the rational method for storm sewers, SCS TR-55 and Haestad Methods Pond-2 computer program methodology for conveyance and detention basin design. Detailed calculations have been placed in an appendix under separate cover which is available for reference by those who desire to review them.

The rational method is used for the design of storm sewer pipe systems. It involves the selection and/or computation of a time of concentration and a runoff coefficient. The time of concentration is the time required for storm water runoff to become established and flow from the hydraulically most distant point (in time not distance) of the drainage area to reach the design point. The time of concentration is usually computed by determining the storm water travel time through the drainage area.

It is assumed that during the time of concentration, the entire drainage area will be contributing runoff to the design point. Consequently, the maximum rate of runoff will occur at this time for a specific design frequency storm. Once the time of concentration is determined, the average rainfall intensity for the design storm frequency of occurrence can

be taken from the Madison, Wisconsin, Rainfall-Intensity-Frequency-Duration Curves.

A minimum time of concentration of 10 to 15 minutes is recommended for analysis of main trunk storm sewer system. Shorter times of concentration may be utilized in lateral storm sewer system design. As the storm sewer runoff enters the system, the flow time in the storm sewer system is then added to the concentration time resulting in a longer concentration time and a lower average rainfall intensity as the storm water flow moves downstream from the initial design point.

The percentage of rainfall that must be collected by a detention pond or storm sewer facility is dependent on the watershed variables such as soil and cover conditions, land use, and antecedent rainfall. These factors are considered when selecting a runoff curve number (CN) in the Soil Conservation Service Technical Release No. 55 (TR-55) and No. 20 (TR-20) method or a runoff coefficient (C) in the rational method for a certain area.

Curve number (CN) values depend on the hydrologic soil group, cover type, hydrologic condition, and antecedent runoff conditions. Soils in the watershed are typically Type B which consist of silt loam or loam and have moderate infiltration rates when thoroughly wetted and consist primarily of moderately deep to moderately well drained soils with moderately fine to moderately coarse textures. The present runoff coefficient throughout undeveloped areas is less than what it will be when total urbanization is reached. The values of the coefficient will increase with the increase in the amount of impervious areas resulting from street surfacing, lawn, development, building construction and grading.

Average runoff coefficients and CN values for each land use were used in the design of storm water management and drainage facilities. For modeling, CN values were determined for each type of existing and proposed land use within each subarea. CN values present the degree of development and percentage of impervious surface in a drainage area. The CN values do not need to be changed for different storm events. Runoff coefficients, for each type of development in the watershed, utilized for the analysis of storm sewer systems and equivalent CN values for antecedent moisture conditions (AMC) Type II distributions are presented in Table 6.

Table 6 - Runoff Coefficients				
Land Use Type	Description	C-Value		CN AMC II
		10-Year	100-Year	
Residential				
Low Density	Suburban Single Family	0.35	0.44	70
Medium Density	Duplexes and Small Lot Single Family	0.39	0.52	74
High Density	Apartments, Town Houses, Condominiums	0.58	0.70	85
Commercial				
	Neighborhood	0.76	0.83	92
	General	0.76	0.83	92
	Downtown	0.76	0.83	92
	Highway	0.76	0.83	92
Industrial				
	Light	0.70	0.78	88
	General	0.70	0.78	88
	Business Park	0.70	0.78	88
Public & Semi-Public				
	Institutional	0.76	0.83	88
	Parks/Open Space	0.28	0.32	61
	Detention Ponds	1.0	1.0	99
Agricultural				
	Row Crops	0.46	0.58	78
	Small Grain	0.39	0.52	72
	Pasture/Grassland	0.28	0.32	60
	Meadow	0.24	0.26	58
	Brush	0.28	0.23	56
	Woods	0.25	0.29	60

As shown in Table 6, the rational method runoff coefficient for a 100-year storm is greater than that used for a 10-year storm. This is based on the assumption that wetter conditions following the 10-year storm period results in greater runoff quantities. Data from Table 6 can be used to calculate overland drainage route capacities. The determination of overland capacities will result in more realistic and more conservative design of flow patterns likely to occur in the system due to a 10-year storm event.

A CN value of 74 for a Type B soil would be equivalent to a runoff coefficient (C) of 0.39 during a 10-year storm event of 4.2 inches of rain in 24 hours. The rational method runoff coefficient (C) indicates the percentage of precipitation that becomes runoff. A comparison of CN values to runoff coefficient for a 100-year storm event (6.0 inches of rain in 24 hours) is presented in Table 7.

Table 7 - Equivalent Curve Numbers to Runoff Coefficients for a 100-Year Storm*		
C	CN	Runoff (Inches)
0.07	40	0.50
0.11	45	0.80
0.17	50	1.14
0.23	55	1.52
0.29	60	1.92
0.36	65	2.35
0.44	70	2.81
0.52	75	3.28
0.61	80	3.78
0.70	85	4.30
0.79	90	4.85
0.89	95	5.41
0.96	98	5.76

* 6.0 inches of rainfall in 24 hours and antecedent soil moisture conditions Type II.

D. Storm Sewer Hydraulics

Storm sewers are the actual conduits to transport storm water runoff from minor storm events. The capacity of a storm sewer conduit is dependent on the pipe slope, pipe diameter, and the roughness of the inner surface of the pipe. The capacity is measured in volume per unit of time, or cubic feet per second as determined by the rational formula. Computations for storm sewer conduit capacity are based on the following Manning's formula:

$$Q = \frac{1.49}{n} \left(\frac{A}{P} \right)^{2/3} (S)^{1/2} A$$

Where:

Q = storm sewer capacity in cubic feet per second (cfs)

n = roughness coefficient

A = cross-sectional area (ft²)

P = wetted perimeter (ft)

S = slope (ft/ft)

A roughness coefficient (n) of 0.013 is used for concrete storm sewer pipe and 0.024 for corrugated metal pipe. This value takes into account losses due to bends and manholes in the system as well as the roughness of the inner pipe surface. Lateral systems with velocities higher than six feet per second or with several manholes should consider head losses due to bends and manholes.

Open channels are normally designed with a trapezoidal cross-section with three feet horizontal to one foot vertical (3:1) maximum side slopes. The same Manning's formula is used to determine channel capacity with the roughness coefficient (n) increased to 0.04. For open channels, P in the equation, becomes the wetted perimeter of the channel.

Storm sewer pipe systems and related facilities have not been analyzed as part of this plan. Storm sewers connecting ponds and pipes larger than 24 inches in diameter are considered trunks. A complete working system consists of channels, ditches, ponds, trunk sewers, manholes, local lines, overland drainageways, inlet leads, inlets, pond inlets and outlets, and all related items. Storm water conveyance systems currently in the watershed and proposed as part of this Plan consist mainly of swales, ditches, open channels, and culverts. *Detailed storm sewer calculations should be provided at the time individual subdivision and site plans are engineered.*

Although local storm sewer systems are designed for ten-year storm events, their performance must be analyzed for storms exceeding the design storm. Surcharging of the system may occur when the design storm is exceeded. During surcharging the system works as a closed conduit, and the pipe network becomes pressurized with different pressure heads throughout the system. Low areas that are commonly provided with catch basins become small retention ponds often performing as pressure relievers (water "gushing out" in some locations). For this reason, it is extremely important to ensure these low areas have an acceptable emergency overland drainage route with proper transfer capacity.

Ponding or standing water on streets must meet the minimum requirements of the 100-year storm design criteria. For safety reasons, the maximum depth of water in local streets should not exceed 1 foot at the deepest point, 6 inches deep in collector streets, and the lowest exposed building elevation should be at least 24 inches above the high water level. The high water level for ponding on streets is defined as the elevation to which water rises before overflowing through adjacent overland routes.

All storm sewer facilities, especially those conveying large quantities of water at high velocities, should be designed with efficient hydraulic characteristics. Manhole and other structures at points of transition should be designed and constructed to provide gradual changes in alignment and grade. Pond outlet control structures should be designed to allow water movement in natural flow line patterns, minimize turbulence, provide good self cleaning characteristics, and prevent damage from erosion.

Catch basins should be liberally provided at all low points where water collects and at points where overland flow is to be intercepted. Catch basin structures are of special importance, since it is a poor investment to have an expensive storm sewer line flowing partially full while property is being flooded due to inadequate inlet capacity. Inlets should be placed to eliminate overland flow in excess of 600 feet or 5 cfs for a 10-year event. Catch basin grates should be of self-cleaning type design to minimize capacity reduction when clogged with twigs, leaves, and other debris.

Effective energy dissipation devices or stilling basins to prevent stream bank or channel erosion at all storm sewer outfalls are recommended. *The following recommendations should be kept in mind when designing a storm sewer outlet:*

- Inlet and outlet pipes from storm water management ponds should be extended to the normal static water level.

- Outfalls with velocities of less than 4 feet per second (fps) flowing into a channel or creek in a direction at less than 30 degrees from the channel axis generally do not require energy dissipators or stilling basins, but do require rip-rap protection.
- Where an energy dissipator is used, it should be sized to provide an average final outlet velocity of less than 6 fps, unless rip-rap is also used. In the latter case, the average outlet velocity should not exceed 8 fps. Local and channel erosion should be considered when designing energy dissipators.
- Where outlet velocities exceed 8 fps, the design should be based on the unique site conditions present. Submergence of the outlet and the installation of a stilling basin are recommended.
- Rip-rap should be provided at all outlets to an adequate depth below the channel grade and to a height above the outfall or channel bottom. Rip-rap should be placed over a suitably graded crushed aggregate material and filter fabric to ensure that soil particles do not migrate through the rip-rap and reduce its stability. Rip-rap should be placed to a thickness at least 1.25 times the maximum stone size and a minimum of 12 inches thick to ensure that it will not be undermined or rendered ineffective by displacement. If rip-rap is used as protection for overland drainage routes, grouting may be necessary.
- Overland drainage routes where velocity exceeds 8 fps should be reviewed and approved by the City Engineer.

Open prairie grass conveyance channels are recommended in lieu of storm sewer pipes to attenuate the storm water flow and increase groundwater recharge by maximizing the portion of runoff that infiltrates into the soil, and improve water quality and enhance the aesthetic qualities of a development. A minimum slope of approximately 1.0% should be maintained in unlined open channels and overland drainage routes whenever possible. We do not recommend that concrete or rip-rap lined channels be designed because water quality benefits are not available with lined channels. Slopes of channels less than 1.0% are difficult to construct and maintain and can create problems with stagnant standing water. Side slopes should be a maximum of 3:1, with 4:1 and gentler side slopes being desirable. Where space permits, slopes should be cut back to match the existing ground level.

Rock rip-rap should be provided at all points of junction between two open channels, at hard corners of the channel, and where storm sewer pipes discharge into a channel. The design velocity of an open channel should be sufficiently low to prevent erosion of its banks and bottom.

the level of an existing pond. *For these reasons, it is recommended that outlets be planned and designed for all existing detention pond areas to mimic pre-development conditions.* A few ponds that are extremely large in relation to their drainage area and have large available storage capacity may be able to discharge sufficient water through evaporation and seepage to prevent damage due to flooding.

Most of the wet detention pond areas in the system collect water from large drainage areas. *To provide proper protection for adjacent property, the design storm interval for wet detention pond design should be for storms up to and including the 100-year storm event as compared to a 10-year storm event design for storm sewer pipe systems.* To provide an additional safety factor, we recommend that lowest exposed floor or opening elevation of a structure in the development should be at least 2 feet above the calculated high water level of the wet detention pond. *We recommend that lowest exposed elevations of structures adjacent to wet detention ponds should be approved by the City Building Inspector prior to basement construction to ensure adequate high water flood protection. All developed land areas should have positive drainage conveyance to detention ponds.*

Runoff determination for detention pond design vary from storm sewer pipe calculations. The critical storm for pond designs is of a longer duration since water is stored for longer periods of time and control released at a slower rate. Computations for pond inflow are based on Soil Conservation Service (SCS) Technical Release 55 (TR-55) methodology which uses CN values to model impervious conditions for a drainage area, time of concentration, a 100-year rainfall intensity of 6.0 inches in 24 hours, and a rainfall distribution Type II. Specifically, computer automated enhanced versions of these analysis methods, as distributed by Haestad Methods, Inc., were used for the analyses in this plan. Another Haestad Methods, Inc., computer program entitled Pond-2 was used to analyze existing storm water management ponds and to determine required design for proposed storm water management ponds.

Detailed calculations have been placed in an appendix under separate cover which is available for reference by those who desire to review them. *Summary of water quantity assessments are provided in Section IX.*

Theoretically, a detention pond water surface elevation will change while it fills and empties, and the rate of discharge will vary with corresponding water surface elevation fluctuations. These changes are not significant in cases where pond elevations change only three to four feet. However, pond outlets should be designed carefully with peak flows at peak elevations taken into account. An underdesigned outlet can create local flooding by detaining more than the design volume of storm water, while an over designed outlet can reduce ponding efficiency, decrease detention time, and overload the downstream system.

Wet detention pond outlet devices that will control outflows larger than three cubic feet per second should be designed to achieve high storage efficiencies. As a matter of policy, large pond outlets should be designed to provide a low outflow rate to a predetermined pond elevation. This design is intended to detain runoff during the early portions of the storm event, allowing the downstream system excess capacity (normally used by the pond outflow) to convey flows from short duration, high intensity storms. City ordinance requires detention basin design to reduce all post-development runoffs to pre-development rates. *Therefore, we recommend the City consider, where feasible, that wet detention ponds be designed for 100-year post development storm event and controlled released at 10-year pre-development runoff rates. The detention pond control structure should also be designed to control storm events less than the 10-year event at or below their pre-development runoff rates.* This design will address both water quantity and water quality concerns within the watershed to the maximum extent practical.

In new developments, special consideration must be given to areas with no overland relief. The excess runoff caused by storms greater than that used for design (100-year event) should be accommodated by ponding in low areas of streets and by flowing through suitable overland drainage routes. Provisions for short-term overland drainage will minimize much of the damage to property which would otherwise occur. Also, overland drainage routes should be provided for emergency overflows and for sediment blockage, snow melt and ice dam conditions.

Where feasible and in areas prone to spills that can contaminate the environment, such as in industrial area wet detention ponds, we recommend that pond outlet structures should be designed to "skim" the flow. "Skimming" the flow can allow a significant amount of time for cleaning and removing undesirable spills, floating debris, and polluting substances. The intent is to reduce potential contamination of downstream water bodies. Skimmers are typically useful for small storm event flows under 3 cfs. Skimming structures for larger flows need to be carefully designed to avoid the creation of vortex or swirl type of action which can transport the skimmed substance. *Also, industrial areas and gas station-type establishments should provide individual on-site containment and storm water runoff pre-treatment systems prior to discharging off-site to the regional storm water management system.*

F. Water Quantity Detention Pond Alternatives

Storm water management detention ponds recommended in this plan can be divided into two types depending on their outlet and storage characteristics.

Detention pond Type A is a wet detention pond that can be a lake or pond with storage volume acquired by a differential in water levels. The outlet elevation is designed at a minimum of four to six feet above the pond bottom elevation which makes this type of pond excellent for water quality treatment. The outlet operates by gravity such as when the water elevation in the pond is above normal static water elevation and the pond begins to release storm water at a controlled rate. A permanent body of water is always maintained assuming that seepage and evaporation do not exceed replenishment. *Due to the emphasis on water quality, special analysis considerations were given in this plan to Type A ponds.*

Detention pond Type B is a dry detention pond that normally contains no water during dry weather. The basin area is either a naturally occurring depression, swamp, marsh, wetland, or is artificially produced by the construction of an embankment across the drainageway such as a road or railroad, etc. The controlled outlet for this type of pond is located to provide complete drainage of the basin. Inlets discharging into the area are usually located at the upper end of the basin so that some overland flow exists from all storm conditions. A shallow ditch shaped passageway would be constructed into these ponds to confine overland flow from the pond inlets to pond outlet points during storms of low intensity and during emptying periods.

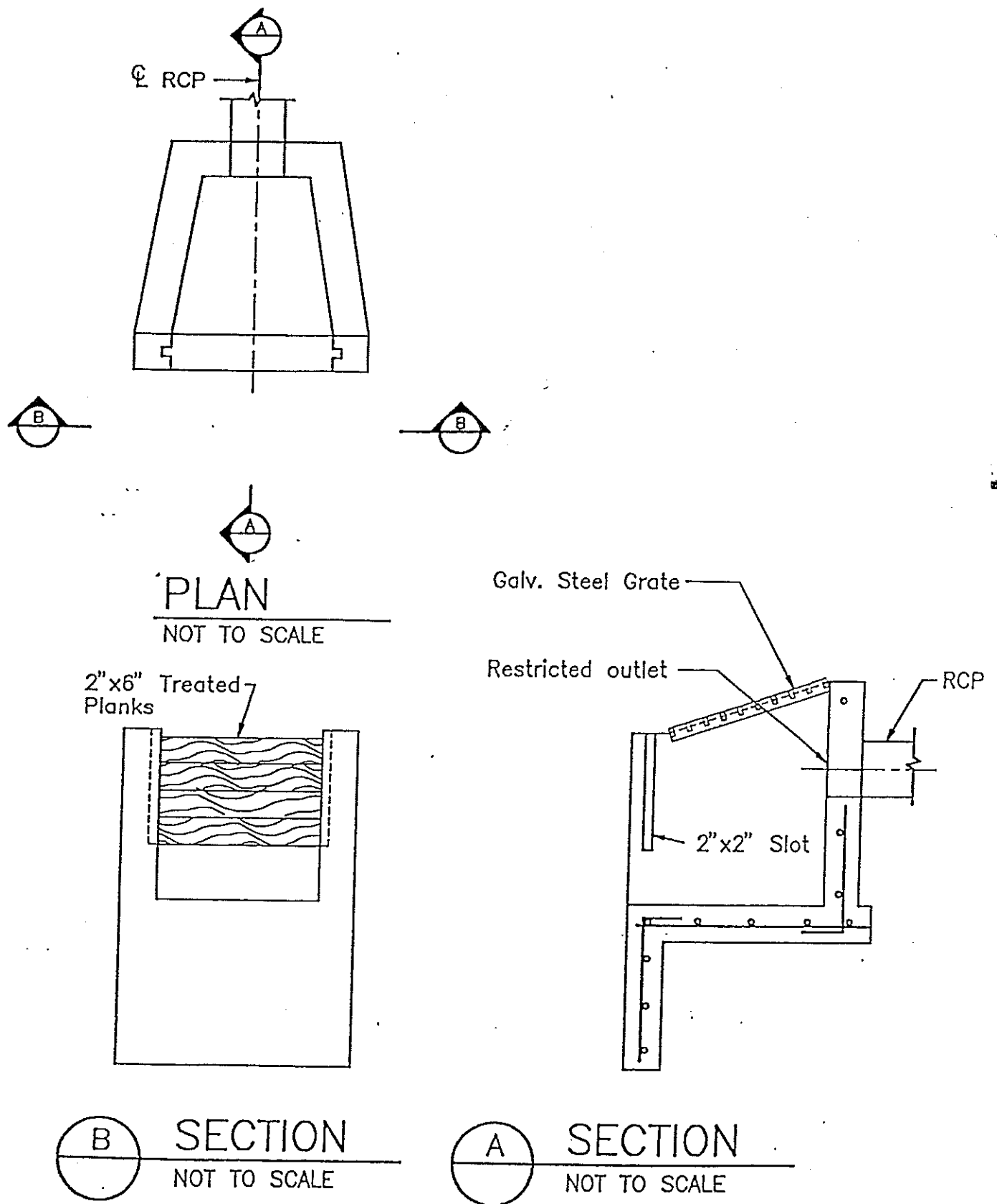
If it is desirable and economically feasible, a permanent wet detention pond Type A can be constructed in the dry detention pond Type B basin. This can be done by dredging out material below the present bottom of the basin, or in cases where hydraulics of the system allow it, the outlet can be raised to provide a desirable depth of water in the basin. If a permanent wet detention basin is desired at a location shown on the master plan map, it can easily be incorporated into this system plan at the time of final design.

An ideal storm water detention pond would have a large surface area with gradually sloping sides combined with substantial storage volume for storm water quantity and water quality purposes. *For water quality purposes, the ideal storm water pond is one which has a permanent pool volume greater than or equal to the volume of runoff from a two-inch storm event under full projected watershed development.* This volume has been derived from design criteria developed under EPA's Nationwide Urban Runoff Program (NURP) with a 25 percent increase in volume to allow for approximately 20 years of sediment accumulation. *To promote sediment and pollutant settling and provide space for sediment accumulation, the mean depth of the permanent pool should be greater than or equal to four feet.* The pond mean depth is equal to the wet volume divided by the pond area at the normal water level. To prevent development of thermal stratification, loss of oxygen and nutrient recycling, the maximum depth of the

permanent pool should be less than or equal to ten feet. The side slopes of any pond should not be steeper than four feet horizontal to one foot vertical (4:1) and, where possible, should not be over ten feet horizontal to one foot vertical (10:1). For safety purposes and to provide suitable habitat for rooted aquatic plants, the bench width should be at least ten feet and the bench slope should not be greater than 10:1 at a point 2 feet below normal static water elevation.

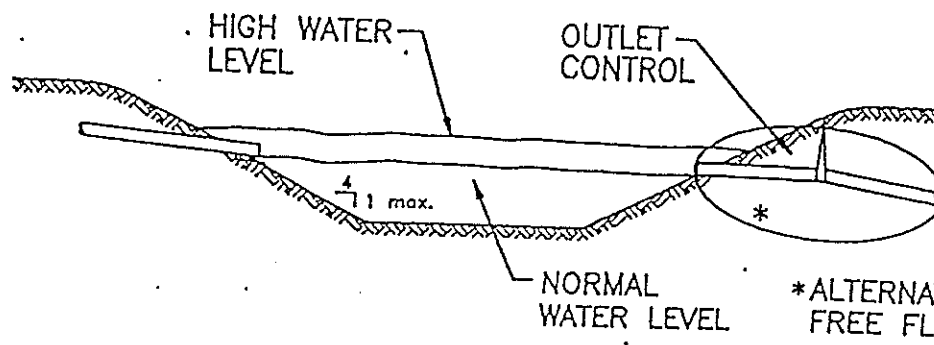
For existing detention ponds that do not have the desired storage capacity, a variety of methods can be used to increase their capacity. The two most common ways are by constructing a dike or a berm to block a drainageway and create an additional artificial pond or by enlarging an existing pond or low area to increase the wet volume and the storage capacity. The increase in storage provided by these methods will reduce the size of overflow pipe required which can result in storm water construction savings for the watershed. Any increase in wet volume reduces the amount of nutrients, sediments, and pollutants flowing to downstream facilities. The need for excavation or berming should be determined at the time of final design and must consider the ecological and wildlife implications.

An alternative to providing wet volume for increasing water quality in drainageways, buffer strips, and shallow lowlands is the planting of native prairie grass vegetation that can trap nutrients, pollutants, and sediments. Wetlands and native prairie grass with small sheet flows have been observed to be as effective as deep water quality ponds to trap nutrients, sediments, and pollutants, and may be more economical to construct. *We recommend that all pond types should be reevaluated during final development engineering and design when all factors affecting runoff, water quality, storage and seepage of the pond have been determined.*



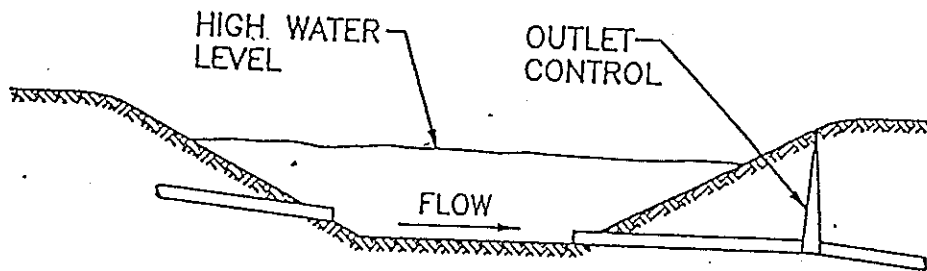
FREE FLOW SKIMMER WITH RESTRICTED OUTLET

FIGURE 7



*ALTERNATE IS FIG. NO. 1
FREE FLOW SKIMMER

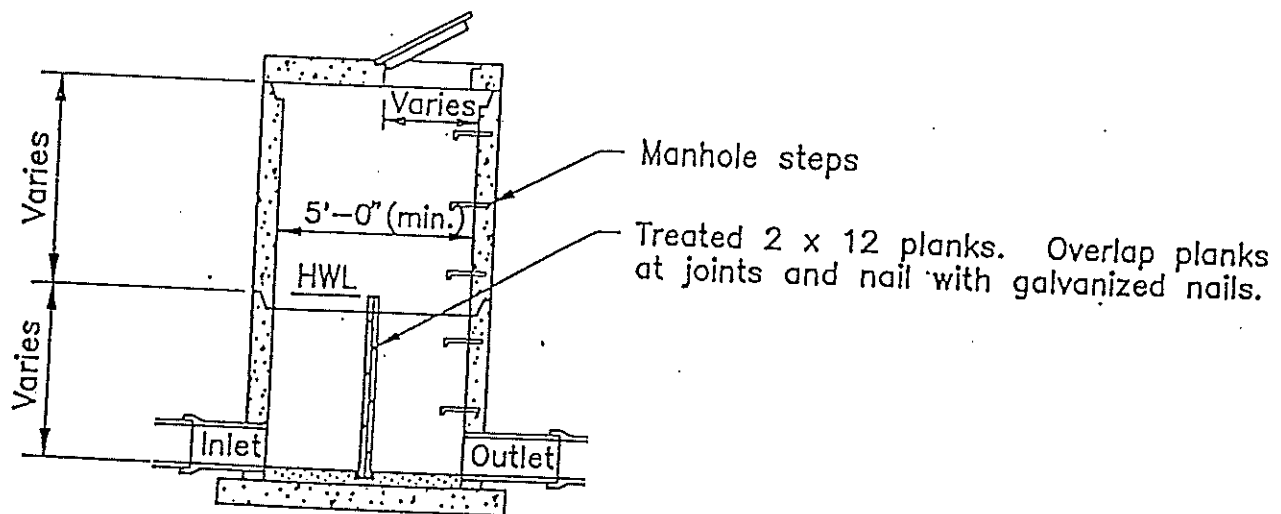
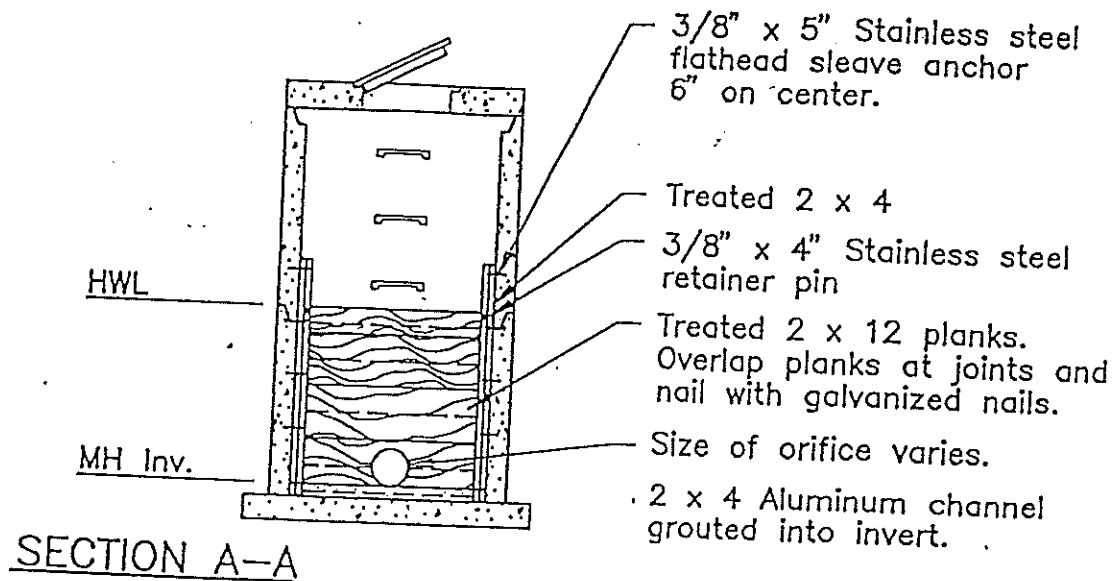
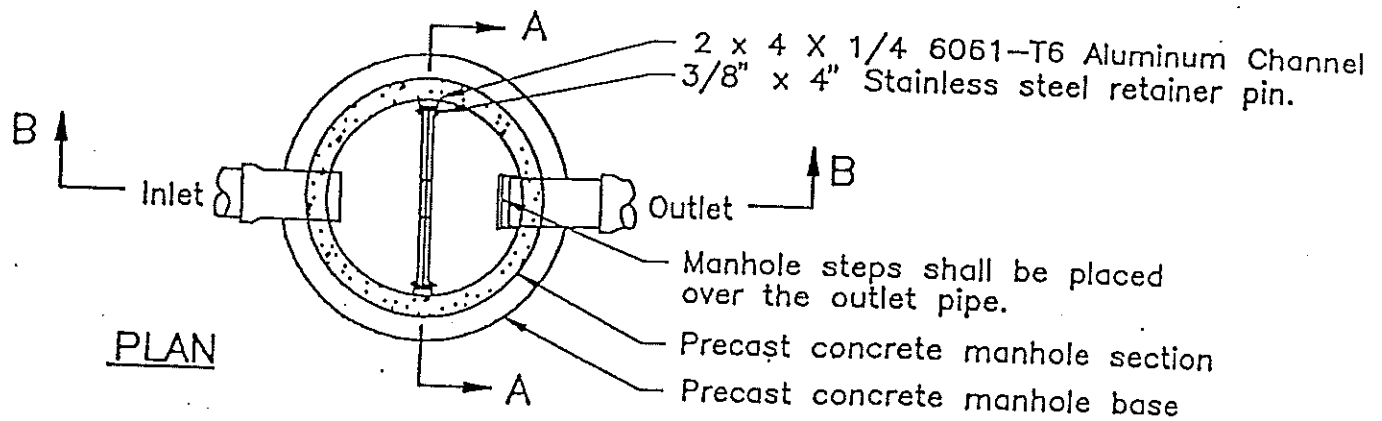
TYPE A: PERMANENT POND WITH STORAGE OBTAINED FROM WATER LEVEL VARIANCE.
GRAVITY CONTROLLED OUTLET.



TYPE B: TEMPORARY PONDING WITH STORAGE OBTAINED FROM WATER LEVEL VARIANCE.
POND NORMALLY DRY.

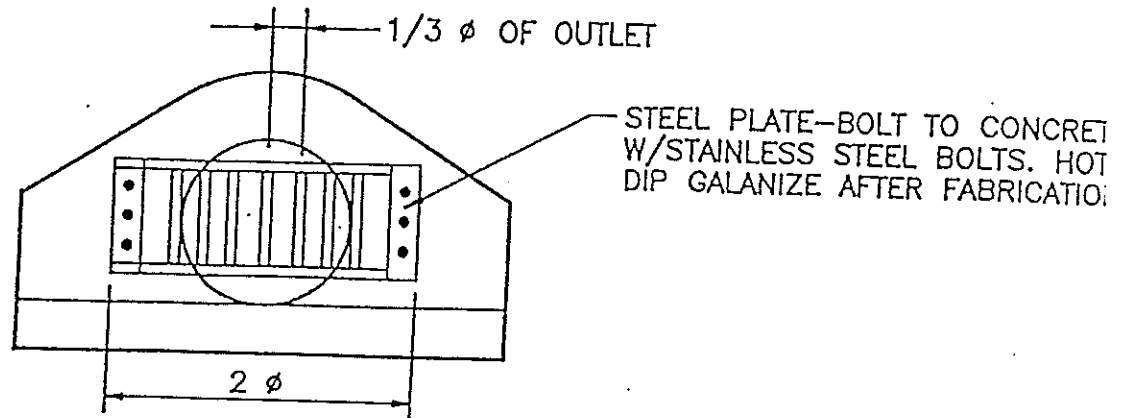
POND TYPES

FIGURE 8

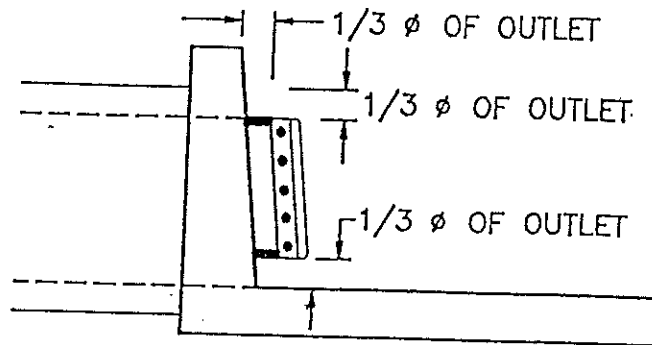


POND OUTLET CONTROL MANHOLE

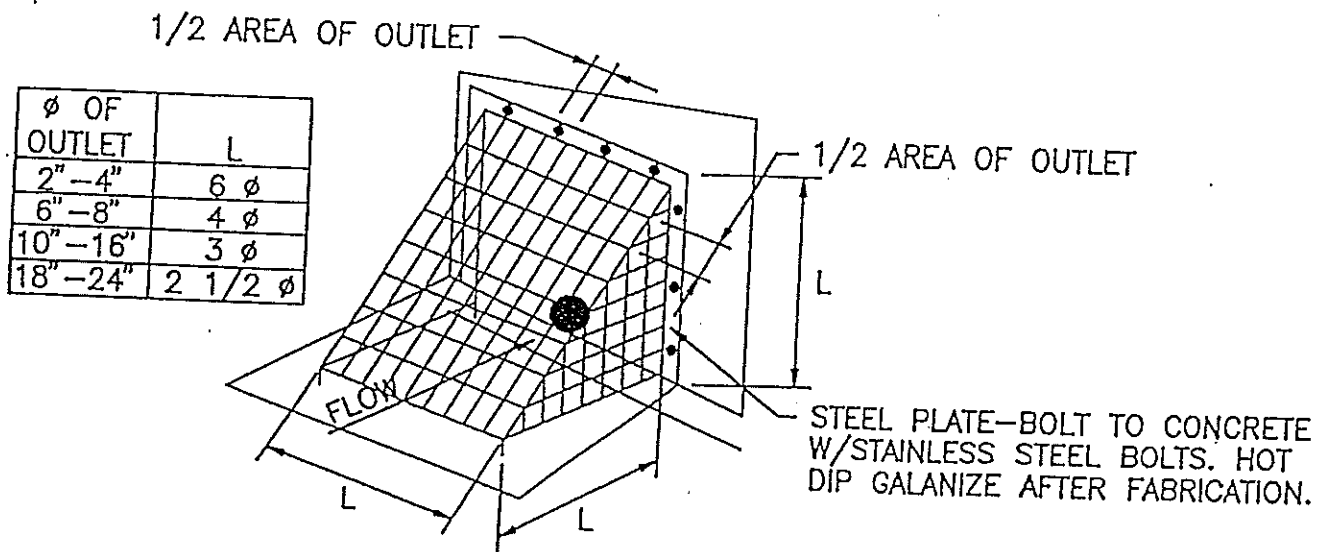
FIGURE 9



FRONT VIEW



SIDE VIEW
BAR SCREEN



MESH SCREEN

DRY POND TRASH RACK DESIGNS
FOR OUTLETS 24" DIAMETER OR LESS

FIGURE 10

G. Detention Pond Open Space Compatibility

Close coordination between a storm water management system and a park or public lands may result in the watershed's efficient use of open space. When open channels are proposed in the system, they can serve as part of a trail system as well as easements provided for installation of storm sewer and sanitary sewer systems.

Since temporary detention ponds are infrequently used to their full capacity, certain parts of these ponds can be used for parks, playgrounds, soccer, and baseball fields that contain recreational facility amenities which will suffer minimal damage from infrequent flooding. *Two alternative methods of combining parks and ponding areas for Type B dry detention ponds are available.* Both methods incorporate terracing of the pond bottom. This provides an added feature for park users recreating in areas adjacent to ponds.

Alternate I consists of an open channel or storm sewer entering a dry detention basin. As described under detention pond Type B, a channel is cut between the inlet and outlet of the pond to convey the runoff from small storms through the pond. The channel is usually designed to handle the flow from a one- to ten-year frequency storm event. Open play areas, picnic areas, and trails could be built on land adjacent to the channel and would have a 10 percent probability of being flooded in any given year.

Alternate II describes basically the same pond as Alternate I, but in this case, the recreational areas have been filled to an elevation that is substantially above the high water level in the channel through the pond. The pond can be designed so the play area is flooded infrequently, such as 4 to 10% probability in any given year. This open space would serve as an excellent recreation area with only an occasional disruption.

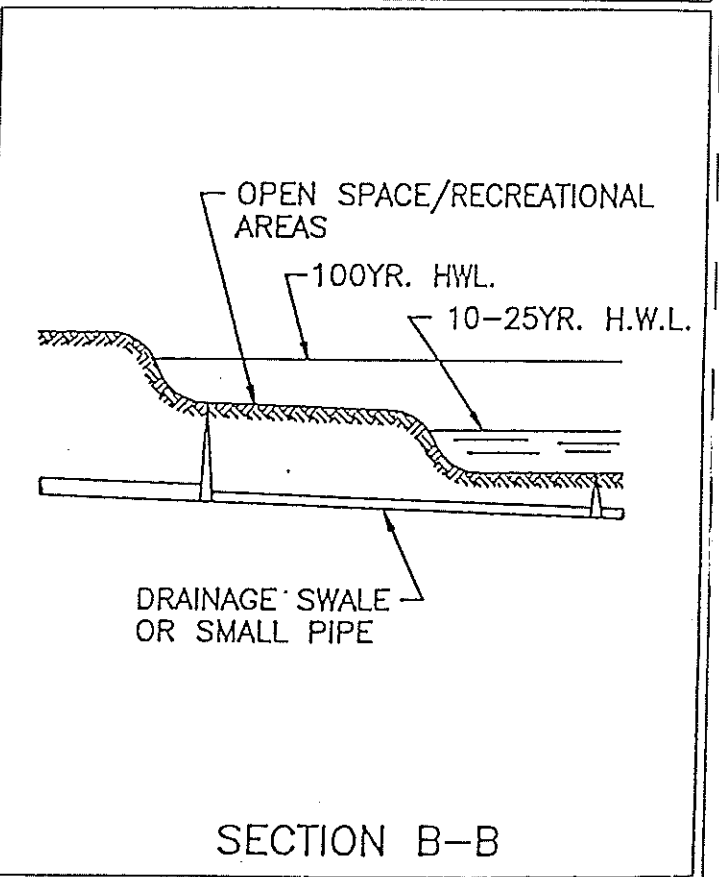
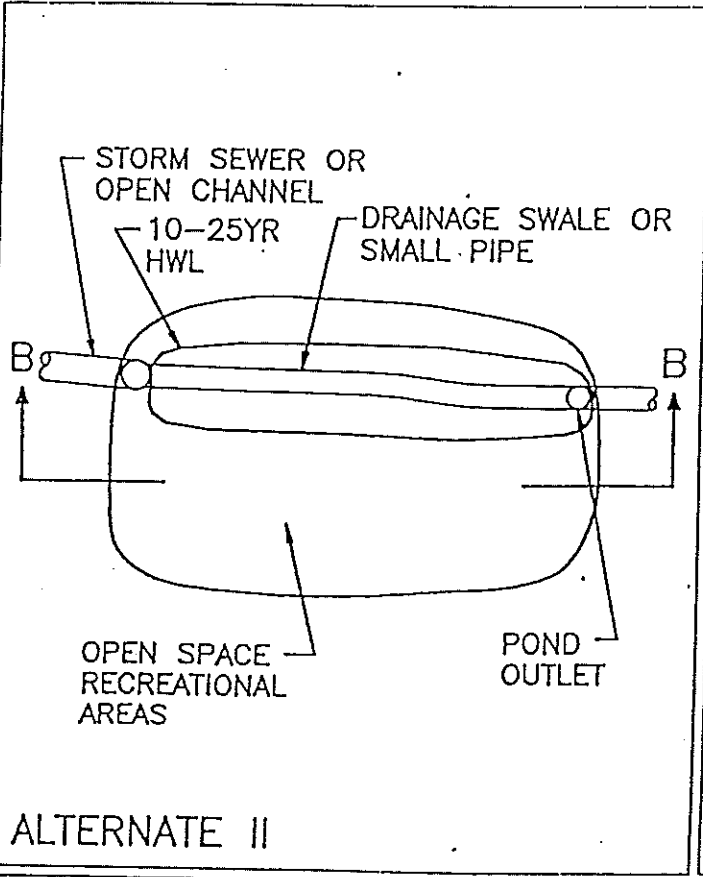
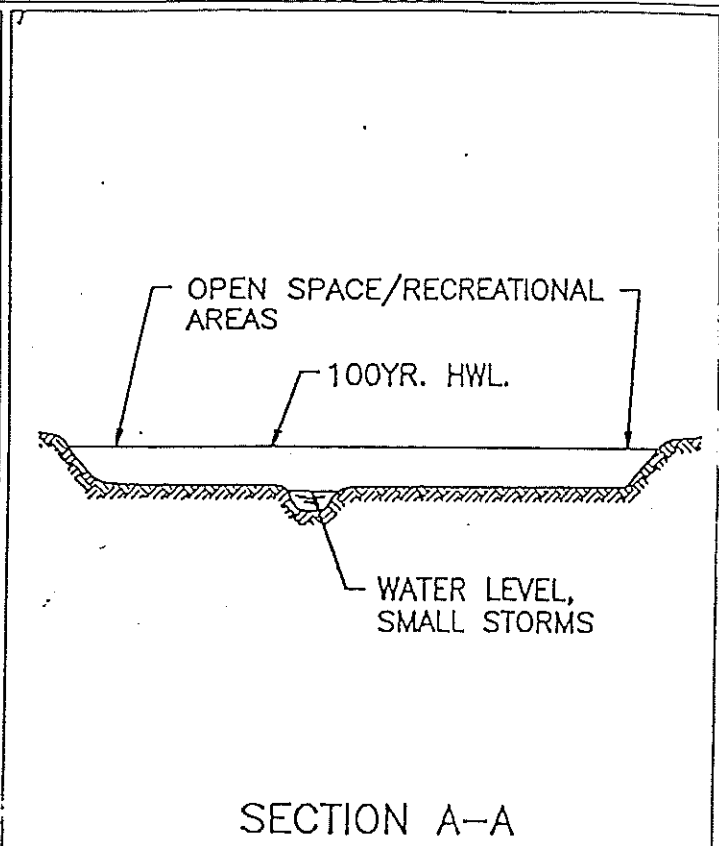
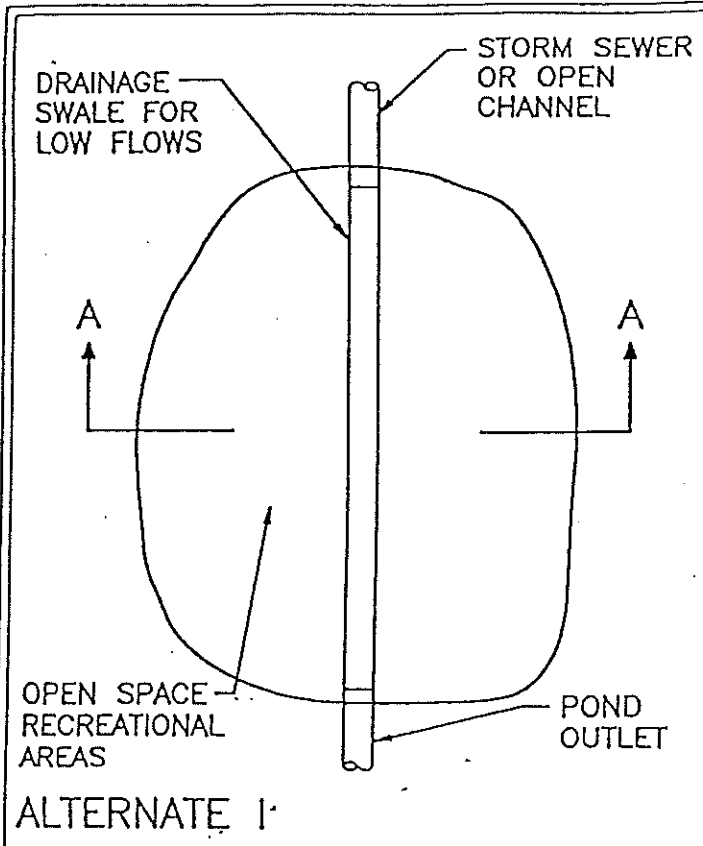
Almost every detention pond Type B and some of detention pond Type A's can be combined with a park or playground. But, because of the varying design conditions for each area, the ponds will need to be carefully designed and engineered so that the desired frequency of flooding is not exceeded.

A trail or pathway system can be coordinated with the proposed detention pond system illustrated in this plan to make the most effective use of the open space. A body of water can be a very desirable amenity adjacent to a trail and homes and, when properly planned, occasional flooding of the trail system will not be a serious detriment. In many cases, the overflow drainage routes and/or storm sewer and sanitary sewer easements can be utilized for a continuation of trail system between areas of open space. The ecological and wildlife aspects of the detention pond system should be

maximized in design, and the proper location of the trail system will allow good access to these areas for wildlife observation.

Recommended elevations for the construction of a park and trail system around and within detention ponds based on inundation times from a 100-year storm are given in Table 8. The inundation time is the time period during which the detention pond recedes to its normal water level after the storm event.

Table 8 - Expected Inundation Time for Recreational Facilities Located Around Detention Ponds	
<i>Facility built at elevation corresponding to:</i>	<i>Expected Inundation Time:</i>
3-year storm	More than 10 days
5-year storm	More than 5 and less than 10 days
10-year storm	Less than 5 days



PARK DEVELOPMENT OPTIONS FOR PONDING

FIGURE 11

Storm Water Quality

VIII. STORM WATER QUALITY

A. General

Surface water quality, groundwater recharge, springs, wetland enhancement and protection are primary environmental issues within the environmental corridor (E-Way) and Lake Monona/Yahara River Priority Watershed. Maintaining the most practical water quality standards in the storm water system is an essential element of the Nine Springs Neighborhood Storm Water Management Plan.

Plants require various substances for growth, including phosphorus, carbon, hydrogen, oxygen, and nitrogen. The concentrations of these constituents in water control the total amount of plant biomass. The quantity of each constituent needed varies. If only one of these constituents is absent, or if there is an overabundance of these constituents, native plants cannot grow, even if the other constituents are abundantly available.

Lakes, ponds, rivers, streams, E-Way and wetlands are biological systems affected by increases in sediment and nutrients, particularly phosphorus. In many water bodies, phosphorus is the least available nutrient; therefore, its abundance or scarcity controls the extent of algae growth. When phosphorus is added to the water body, the algae population increases. A eutrophic or nutrient rich water body tends to be shallow, "green", and has limited oxygen. Eutrophication is the process by which water bodies are fertilized with nutrients (chemicals absorbed by plants and used for growth). It is a natural aging process, but human activities can speed it up. As nutrients such as nitrogen, phosphorus, and potassium wash into water bodies in runoff water by soil and erosion, they fertilize the water allowing algae, non-native invasive vegetation, and nuisance weeds to grow. As plants die and decompose, they accumulate on the bottom of water bodies as muck (organics). The combination of this process with a continuous erosion process eventually converts the water body into a shallow low quality wetland.

Increased sedimentation and phosphorus concentrations can cause major changes in the ecological and biological communities of water bodies. Because game fish are more sensitive to low oxygen conditions, rough fish, carp, and bullheads eventually replace most of the sunfish, bass, and northern pike in lakes. In some instances, all of the oxygen in a lake is used up by decaying algae during the winter causing a major fish kill. Increased algae and macrophyte growth will escalate the build up of sediments in water bodies.

The water that runs off agricultural lands, city streets, parking lots, driveways, and lawns carries a heavy load of pollutants to the nearby E-Way, wetlands, lakes and streams. Although some pollutants found in urban runoff are unique to urban areas, others are similar to the pollution found in rural runoff. Both urban and rural runoff carry "conventional" pollutants: sediment, nutrients, oxygen-demanding materials, and bacteria. Runoff from urban and industrial areas typically contains significant quantities of the same types of pollutants found in waste waters and industrial discharges, including heavy metals, oil and grease, insecticides, herbicides, pesticides, nutrients, and organic compounds. By early recognition of the problems and implementing recommended best management water quality practices, the City of Fitchburg and the watershed can maintain or enhance the surface water quality within the E-Way, wetlands and Lake Monona/Yahara River Priority Watershed.

The main sources for degradation of water quality are associated with human activities; farming, construction, industrial activities, and road maintenance. Everyday activities generate residuals that are transported by storm water runoff or snow melt to a storm sewer, drainageway, channel, swale, ditch, etc. Water resources are directly affected by substances that are conveyed in storm water such as sediments, motor and transmission oils, anti-freeze, paint, detergents, wax, fine dusty residuals from tires, brakes, and street wear, lawns and farming fertilizers, herbicides, pesticides, and numerous other wastes.

Industrial areas are known for having toxic pollutants. Forms of toxic pollutants come from synthetic sources such as heavy machinery, vehicle exhausts, smokestack emissions, weathered paint, roofs, parking lots, motor and lubricating oils, and wood preservatives. Heavy metals are typical in variable concentrations in industrial runoff. Heavy metals include, among others, chromium, cadmium, copper, lead, mercury, nickel, and zinc. Some of these, especially lead, zinc, and copper are known to be toxic to aquatic organisms and can bioaccumulate in fish and can transfer to humans.

Table 9, developed by the Wisconsin Department of Natural Resources and the US Geological Survey, illustrates the percent of time traceable pollutants found in Wisconsin's urban runoff. DNR data indicates that sediments, nutrients, heavy metals and pesticides occur frequently in urban runoff and need to be targeted in the Nine Springs Neighborhood storm water quality management program.

Table 9 - Pollutants in Wisconsin Urban Runoff	
Metals and Inorganics	Percent of Occurrence
Cyanide	12%
Silver	31%
Mercury	34%
Cadmium	43%
Antimony	51%
Arsenic	81%
Chromium	98%
Copper	98%
Lead	98%
Nickel	98%
Zinc	100%
PAH's, PCB's, and Phthalates	Percent of Occurrence
Chrysene	12%
Benzo (GHI) Perylene	12%
PCB's	17%
Phenanthrene	19%
Pyrene	23%
Flouranthene	31%
Bis Phthalate	48%
Benzo A Pyrene	98%
Pesticides	Percent of Occurrence
Aldrin	15%
Heptachlor	15%
Cyanizine	22%
Metolachlor	26%
Lindane	29%
Chlordane	29%
DDT	36%
Methozychlor	44%
Malathion	49%
Alachlor	52%
Dicamba	56%
Atrazine	59%
2, 4-D	67%
Diazinon	82%

B. Erosion and Sediment Control

In areas such as the Nine Springs Neighborhood, where development will take place, the storm water frequency contains substantial quantities of sediments. This is due to agricultural practices, construction grading and inadequate erosion control practices. Erosion is a process of detachment and transportation of soil particles. Erosion in agricultural areas and developments comes in the form of gullied waterways, rilled and gullied slopes, undercut pavements and pipelines, and lost topsoil.

The natural processes of erosion, transport, and deposition of sediments have occurred throughout geologic times and they have shaped the landscape of the watershed. Eroded soil is the largest pollutant of surface waters in the United States. Sediment transport affects water quality and its suitability for consumption, industrial use, recreation, wildlife and ecological sustainability. The source of most sediments transported by Nine Springs Creek, Swan Creek, channels, drainageways, and storm sewers to receiving water bodies is soil eroded from upland areas. Erosion often causes serious damage to agricultural land by reducing the fertility and productivity of soils.

Problems associated with deposition of sediments vary. Sediment deposition in stream channels reduces the flood carrying capacity, which results in greater flood damage to adjacent properties. Receiving water bodies trap the incoming sediment load and flood risks increase due to aggradation upstream. Upstream aggradation depends on the stream slope, the sediment size distribution, and the water-level fluctuations in the receiving water body. Streams, drainageways, and channels with minimal slope carrying large quantities of sediment result in aggradation many miles upstream of the receiving water body. Receiving water body sedimentation results in loss of storage capacity for flood control.

Human activities increase the rate of erosion over the normal erosion rate, also known as the geologic erosion rate. The erodibility of natural soils may be altered when the soil's natural condition is disturbed by plowing, tillage, and construction type activities. Erosion rates accelerated due to human activities can be more than 100 times greater than geologic erosion rates of 0.10 ton/acre-year. Erosion rates of grazed areas can exceed 5-tons/acre-year, and we can expect average values of 40 to 50 tons/acre-year during urban construction development when the soil is not vegetated and it is constantly reworked. Human activities also influence the natural characteristics of channel flows through channel stabilization and installed hydraulic structures.

The extent of erosion and sediment loading from the watershed relates to a complex interaction between topography, geology, climate, soil, vegetation, land use, and man-made developments. Erosion and sediment loading includes the detachment and transport of solid particles from the land surface or from the bed and banks of streams, channels, and drainageways. Erosion occurs in various forms by water, gravity, wind, and ice. A complete cycle of erosion and transport creates sedimentation.

Water is the most common agent of erosion. Water erosion includes sheet erosion and channel erosion. Sheet erosion is the removal of land surface material due to rainfall and thawing ground and its subsequent removal by overland flow. The impact of rainfall causes the removal of soil material. Sheet erosion can include rill erosion, which is the removal of soil by concentrated sheet flow. Rills are usually small enough to be removed by normal tillage.

Wind erosion can be important in arid and semiarid areas. The rate of wind erosion primarily depends on the soil particle size, wind velocity, soil moisture, surface roughness, and vegetation cover.

When large amounts of rainfall and snow melt runoff occurs during spring months and there is minimal vegetative soil cover and freeze-thaw cycles that cause weathering, extremely high erosion rates and sedimentation loads are recorded. The major portion of the annual sediment load from the watershed can be observed during spring snow melt runoff.

1. Sources of Sediment

a. Urban and Rural Areas

Both rural and urban areas contribute to sediment loads. Soil erosion is the primary source of sediment. Typically, older parts of the City may have less soil erosion than rural areas since the land consists of established homes, grass, and pavement. The concentration of sediment is generally lower in low and medium density residential urban runoff than in rural runoff. However, the total amount of sediment from low and medium density residential urban areas is comparable to rural areas since more water runs off man-made impervious surfaces in developed areas.

b. Construction Sites

Although existing urban areas such as parking lots and street surfaces are important sources of sediment, by far the

highest amounts of sediment come from areas under construction. *Studies and research estimate that an average unprotected acre under construction delivers 60,000 pounds (30 tons) of sediment per year to downstream waterways. This is about 60 times more than any other land use.*

Two factors account for the importance of construction sites as sediment sources:

- High Erosion Rates
- High Delivery Rates

Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to one to three tons per acre per year for cropland or low density residential areas.

Construction sites have high erosion rates because they are typically stripped of vegetation and topsoil for long periods of time. More importantly, construction sites have very high delivery rates compared to cropland. During the first phase of construction, the land is graded and ditches or storm sewers are installed to provide good drainageways. This efficient drainage system does not allow sediment to settle out. While some of the sediment from croplands is filtered out by ground cover, or deposited in a low spot or on the next field downhill, most soil erosion from a construction site gets delivered directly to the E-Way, wetlands, creeks and/or lakes.

Section X Best Management Practices and Appendix D provides reference to the City of Fitchburg's adopted Chapter 27 Erosion Control and Storm Water Management Ordinance for protection of the City's unique natural resources by minimizing the amount of sediment carried by runoff or discharged from construction sites to the E-Way, perennial waters, wetlands, and public rights-of-way within the watershed.

c. Channel Erosion

Channel erosion, which includes bed and bank erosion, can be very significant in channels with changes in flow volume. The sediment transport capacity of a channel is proportional to the amount of discharge and channel slope. This capacity varies inversely with bed sediment size. Channel bed erosion rates can be determined by comparing the actual

cross-sectional geometry with earlier profiles. Channel bank erosion rates can be measured by comparing channel positions from a pair of recent aerial photographs to an old set of aerial photographs. Field observations and review of aerial photographs have confirmed that a considerable amount of channel erosion is present in the watershed.

d. Changes in Flow

From the beginning of farming and construction, urbanization and agricultural practices dramatically change the cycle of water movement. Clearing land removes much of the vegetated cover that intercepts rainfall before it reaches the ground. Once the trees and grasses are gone, less water is returned to the air through evaporation or transpiration (loss of water vapor from plants). Instead, rain falls directly on the exposed soil.

As farming, construction and land disturbing activity proceeds, soil conditions also change. During construction, topsoil is usually stripped away and heavy construction equipment compacts the remaining subsoil which affects what happens to rain water that falls on the site. Less water soaks into the ground after the "spongy" layer of topsoil is removed. More water runs off the compacted subsoil rather than percolating down to recharge groundwater supplies. Water that once seeped through the upper layers of soil as interflow now runs off the surface. The loss of the shallow groundwater is significant because it supplies much of the baseflow in springs, the E-Way, and creeks between storms.

In many farming and development projects, major grading changes the shape of the land surface to provide better drainage. Farming, construction and land development design fills low spots and wetlands to provide more "farmable" and "buildable" land. These natural depressions or detention areas no longer collect and store storm water for gradual release after a storm. Instead, storm sewers or ditches are built to improve drainage by carrying runoff, sediments, and pollutants directly to the E-Way, wetlands, Nine Springs Creek, Swan Creek, Yahara River, and lakes.

Storm water runoff problems continue even after developers and builders complete construction. Water runs off hard (impervious) surfaces covered by parking lots, buildings, and streets picking up speed and carrying sediments and

pollutants along the way. Developers and builders can help mitigate potential damage by spreading salvaged topsoil and planting native prairie grass vegetation to allow the soil to regain its ability to soak up and infiltrate storm water runoff.

The amount and timing of changes to the E-Way, wetlands, creeks, drainageways, and channels are already occurring and will increase sediment and pollutant loading in the following ways:

- **Peak Discharge:** After farming and development, peak stream flows are two to five times higher than they were before farming and development. Consequently, the frequency and severity of flooding and sedimentation increases. A stream that once overflowed its banks once every two years may now flood three or four times per year. When the banks overflow, sediments are deposited within the flood plain or transported downstream.
- **Volume:** The volume of runoff increases about 50 percent in a moderately developed or altered watershed.
- **Timing:** Urban and farm drainage systems are so efficient that the time required for runoff to reach the stream can decrease as much as 50 percent. This results in high flows compressed into a shorter period of time. The E-Way, wetlands, creeks, drainageways, and channels are "flashy" because water levels rise and fall very quickly in response to storms.
- **Velocity:** Flow velocity increases in the E-Way, wetlands, creeks, drainageways, and channels during storms because peak discharges are higher, and new drainage systems are smooth and efficient.
- **Baseflow:** Stream flow is reduced by farming and development activities. Portions of channels and drainageways that were once wet and flowed year-round become seasonally dry.

Described above are the dramatic flow changes in the E-Way, wetlands, creeks, drainageways, and channels that have extensive consequences in terms of flooding patterns, channel erosion, ecological and wildlife habitat degradation.

2. Consequences of Increased Sediment Loading

a. Channel and Floodplain Impacts

Under natural conditions, the E-Way, wetlands, creeks and drainageways develop a channel large enough to hold approximately a two-year peak flow, the highest flow that has a 50 percent probability of occurring in any given year. Therefore, the conveyance systems are somewhat larger than the average annual flood.

Urbanization and farming activities significantly increase the typical two-year peak flows. In response, the conveyance systems erode to form a larger channel. The creek, river and drainageways become two to four times wider after farming and urbanizing within the watershed.

Channel erosion is often quick and severe because most floodplain soils are loose and wash away easily. However, downstream transport of eroded sediment is slow and moves gradually as "bed load".

Bed load is the total rate of sediment transport for sediment particle sizes readily apparent on the surface of the river bed in the processes of rolling, sliding, and/or hopping. Movement of these particles is related to the flow and sediment characteristics of the bed. These constantly shifting deposits form dikes, sand bars, and smother bottom ecological and aquatic life for many years.

The floodplain and the channel of the creek become wider as farming and development occurs in the watershed. Just as the two-year peak flow increases, so do peak flows for larger storms. Land, buildings, and homes that were once safe from the 100-year storm may now be at risk.

b. Lost Value of Natural and Water Resources

Increased sediment loadings directly influence the value of the E-Way, springs, wetlands, water bodies, creeks, streams and lakes. Sedimentation and a variety of toxic pollutants conveyed by storm water runoff make waterways and wetlands unsafe for people, fish, and wildlife.

For example, water turbid with sediment or inundated with algae makes feeding difficult for sight feeders like northern pike and waterfowl. Smallmouth bass are especially sensitive to sediment deposits that smother the gravel creek and lake bottoms where they spawn. Low oxygen content, warm discharge temperatures and sediments are intolerable for trout. Toxic chemicals that attach to sediments may affect fish and waterfowl in a variety of ways varying from disorientation, impaired reproduction, lowered disease resistance, or even death. Over time these individual impacts add up to three major changes in fish and waterfowl populations:

- Diversity Decreases
- Abundance Decreases
- Pollution-Tolerant Species Replace Pollution-Sensitive Species

The high flows and pollutants typical of agricultural and urban runoff create serious problems for aquatic insects that fish and waterfowl feed upon. High flows may scour these organisms from some parts of the ecosystem while sediment deposits may smother them in other areas. Toxic chemicals attached to sediments may kill aquatic insects or affect their ability to feed and reproduce.

As waterfowl and fish populations change, rural and urban water resources become less valuable for recreation and tourism. The Yahara River, tributary streams and creeks, lakes, and other inland ponds will be populated by carp, catfish, Buffalo, and suckers which are less popular for recreational fishing than panfish, Northern Pike, and Smallmouth Bass that are typically found in unpolluted waterways. There is also concern about some fish being unsafe to eat due to contamination with toxic chemicals that attach to sediments.

In addition to losing fishing and hunting value, the E-Way, creeks, wetlands, and drainageways will also lose value for other types of recreation. If they are turbid with sediment or algae and loose native vegetation they are less attractive for boating, swimming, hiking, bicycling, fishing, hunting, sightseeing, and picnicking. If bacteria and toxic chemical concentrations become too high the water may become unsafe for swimming and other body contact recreation. When the E-Way, springs, wetlands, drainageways, and lakes lose their recreational and aesthetic values, they will become more impaired and less desirable over time.

3. Sediment Control Methodology

During farming operations and construction, a substantial amount of suspended solids (sediment) can enter unprotected downstream water bodies, even if on-site erosion control practices like silt fences, straw bales, stone weepers, or vegetative cover are put in place. Pursuant to the City's Erosion Control Ordinance and under these construction circumstances, developers are required to excavate sediment traps and barriers in low areas of the development site. These sediment traps will intercept storm water with sediment from the property and prevent sediment from entering the E-Way, creeks, rivers, drainageways, wetlands, Yahara River, and lakes. Temporary ponding and sediment storage should be provided with control release structures and emergency overflows to ensure that no serious property damage occurs during high-intensity storms while sediment ponds are in use. After development, the sediment ponds can be filled and the area connected to the Nine Springs Neighborhood storm water management system or the sediment pond may be included with permanent on-site storm water management system. *We recommend that the sediment problem be mitigated by limiting and/or programming the area under mass stripping and earthwork operations at any given time.*

Even when precautions are taken during construction, a large amount of sediments may still enter the drainage conveyance system. For this reason, it is desirable to minimize the chances of these sediments reaching E-Ways, drainageways, the Yahara River, wetlands, and lakes. *We recommend that sedimentation basins, traps, and siltation basins or structural controls be engineered and located at the point of discharge from the construction site prior to discharge into a sensitive receiving water body. These erosion control measures should be installed at the time of construction and prior to any land disturbing activities.* Figure 12 depicts several types of sediment and nutrient removal and/or siltation structures. These are:

- Structure A requires the condition or provision of a shallow area between the storm sewer and the water body.
- Structure B involves the use of a precast concrete structure settling basin.
- Structure C is an available option when a natural site for a siltation structure is not present or the excavation of a sedimentation nutrient removal pond is not feasible.

We recommend that sediment and nutrient removal structures should be installed wherever a storm sewer discharges into a sensitive priority water body. In certain cases, settling chamber (sump) type catch basins or manhole structures can easily be provided in storm sewers prior to discharge. These structures can effectively provide removal of sediments, sand, and gravel that may be flushed down the storm sewer from parking lots, streets, and highways. These sump structures are not effective in the removal of nutrients and finer particles such as silts and clays. The use of sumps should be limited to areas where they can be regularly maintained and can realistically be expected to intercept the sand from winter sanding operations and gravel from driveways, parking lots, or development construction. A sediment removal structure must be regularly maintained if it is to remain effective.

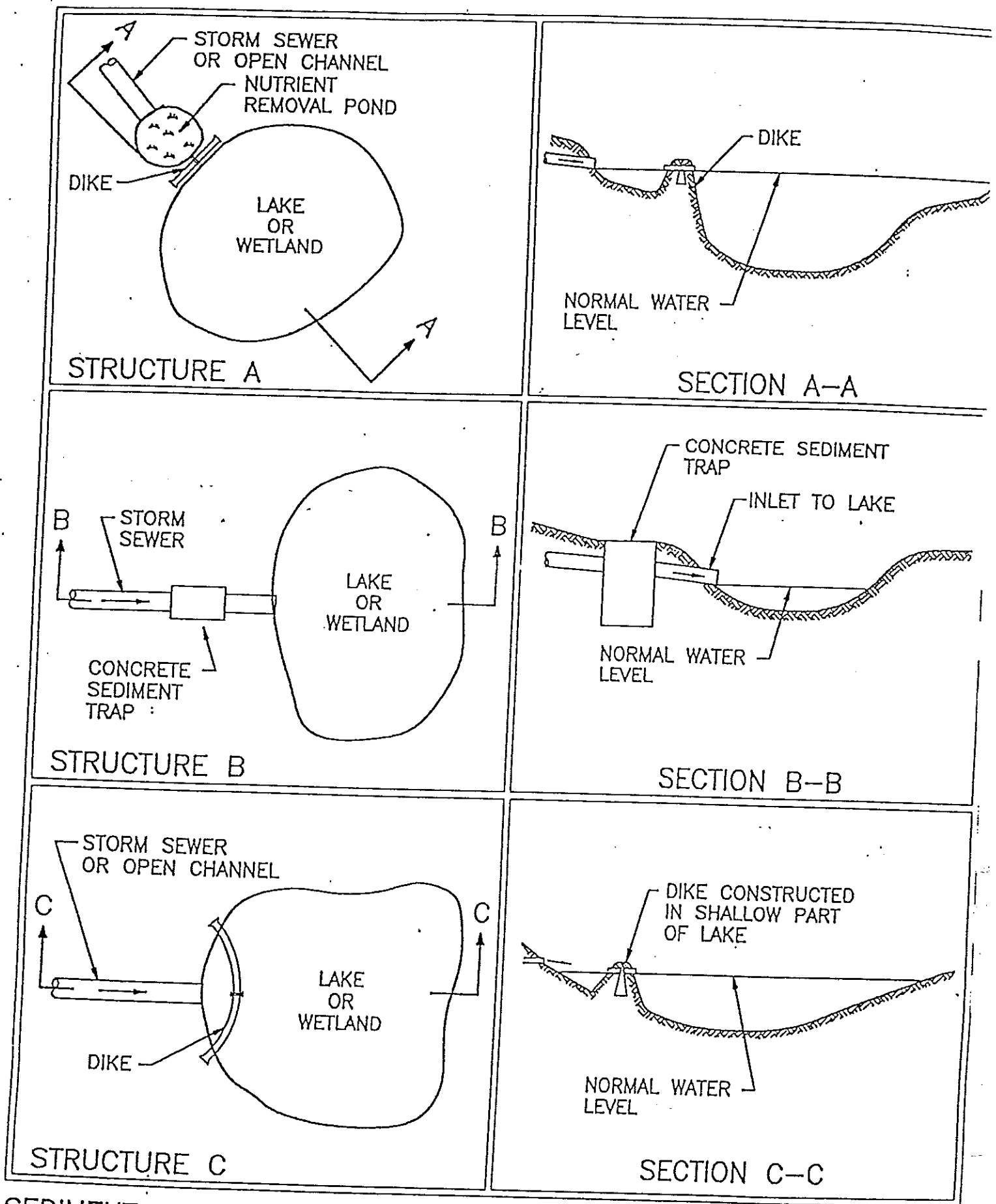
Another available option when a natural site for a sedimentation structure is not present or permitted is the excavation of a sediment and nutrient removal pond. The location and geometry of these ponds can be modified, but the required surface area and mean depth must be provided if removal efficiencies are to be obtained. *We recommend that the sediment and nutrient ponds be constructed with an emergency overflow at or above the 100-year flood elevation of the adjacent body of water so that no short circuiting occurs between the pond's inlet and outlet.*

If the outlet for a sedimentation/siltation basin is located below the normal water surface, these basins can also serve to confine floating solids and debris that may otherwise enter the E-Way, creeks, drainageways, wetlands, and lakes. Periodic skimming of the basin to remove floating solids can be accomplished once or twice a year. If a major "spill" of a hazardous product such as gasoline or fuel oil occur, it would be retained within the basin and provide a point of easy access for prompt appropriate cleanup.

Even with the best and most expensive sediment removal system, contamination of ponds, the E-Way, creeks, drainageways, wetlands, Yahara River, and lakes will occur unless careful attention is given to the use of the land. However, the negative impact of increased sediment and nutrient loads can be minimized by following pollution prevention and source controls throughout the watershed. Property owners must use care in the development of their yards such as sodding bare areas and good management practices after the initial period of lawn establishment. Farmers must follow good land management practices. Also, developers must minimize erosion during grading and building construction following the City of Fitchburg Chapter 27 Erosion Control and

Storm Water Management Ordinance and the Wisconsin Construction Site Best Management Practice Handbook. This ordinance needs to be enforced and followed to the maximum extent practical.

Additional recommended sediment and erosion control best management practices are provided in Section X and Appendices D, F, and G.



SEDIMENT & SKIMMING STRUCTURES

FIGURE 12

C. Treatment Based Storm Water Quality Control

There are many methods of practice available for controlling storm water quality including volatilization, absorption, biofiltration, and sedimentation. Volatilization and absorption includes aeration and infiltration. These methods are used in highly impervious areas with high pollution potential, but have limited capacity to treat runoff from large areas. These types of treatments are very expensive and are not cost effective for areas larger than 20 acres.

Biofiltration and sedimentation include the use of grass and prairie grass filter strips, grass swales, wet detention basins, constructed wetlands, infiltration basins/dry detention basins, extended wet detention ponds, multiple wet and dry pond systems, infiltration trenches, sand filters, filter strips, and water quality inlets/oil grit separators. *These methods are more practical and economical for large areas in the control and treatment of storm water quality.* Each of these methods must be evaluated at the time of engineering and design for practical effectiveness because each practice is site specific and may not be applicable for every type of land use and site conditions. Section X provides additional recommended best management practices for water quality control. *Appendix G provides a BMP Fact Sheet Summary Assessment of the various best management practice options available and recommended to address storm water management.*

The main methods of practice used in evaluating treatment for the Nine Springs Neighborhood watershed storm water runoff are wet detention basins, grass and prairie grass filter strips and swales, and constructed wetlands. Because the watershed storm water management plan is based on a regional approach analysis methodology that takes advantage of existing topography and undeveloped land, wet detention basins and prairie grass filter areas generally become the most cost effective method of treatment for water quality improvements. Wet detention basins also provide water quantity storage and flood mitigation benefits. A permanent pool of water is a good design option because it allows for sedimentation, absorption, and biological uptake to occur; increases sedimentation efficiency and reduces bottom scouring potential; and provides habitat for algae and aquatic plants that can assist in the removal of soluble pollutants and promote wildlife. *Wet detention basins and prairie grass buffer areas also are the most economical for the City to operate and maintain.*

The United States Environmental Protection Agency (EPA) National Urban Runoff Program (NURP) studies and SLAMM development have shown that wet detention basins, in which permanent pools of water are maintained, are very effective for reducing loadings of suspended solids (sediments), heavy metals, and nutrients from urban and rural watersheds. Wet detention systems trap sediments and pollutants that

attach to sediments such as PCB's, copper, lead, zinc, phosphorus, diazine, alachlor, etc. Table 10 depicts the benefits of wet detention ponds as measured by the DNR for Wisconsin.

Table 10 - Benefits of Well Designed Wet Detention Ponds	
Pollutant	Average Reduction
Phosphorous	60%
Lead	70%
Zinc	70%
Bacteria (400/100 ML)	70%
Diazinon (Pesticide)	17%
2, 4-D	15%
Alachlor	57%
Phtholate	80%
Sediment	90%

Table 10 Source: Wisconsin DNR Storm Water Manual - Part One

An ideal storm water pond with wet detention for water quality is one that has a large surface area with gradually sloping sides to provide substantial storage volume for storm water quantity and quality purposes. *For water quality purposes, the ideal storm water pond is one that has a wet storage volume greater than or equal to the volume of runoff from a two-year storm event on a fully developed watershed and increased by 25% for sediment storage.* This volume will satisfy the NURP recommendations. The side slopes of any pond should not be steeper than four feet horizontal to one foot vertical (4:1) and, where possible, should not be less than ten feet horizontal to one foot vertical (10:1). Section X provides additional design criteria for wet detention basins. Appendix G provides a BMP Fact Sheet Summary Assessment and some additional design criteria for wet detention basins.

Appendix B - Map #4 depicts recommended locations of wet detention ponds and grass/prairie grass buffer areas designated to provide water quality and water quantity benefits. *We recommend that surface areas and mean depths mentioned above and in Section IX should be provided in order to achieve the estimated removal efficiencies. We recommend that water quality ponds be designed with prairie grass vegetative buffers for additional erosion protection, sediment and pollutant removal.* Removal of accumulated sediment and pollutants in water quality ponds will be required at periodic intervals in order to maintain performance. *Because dredging costs can be high, we recommend that water quality ponds be designed for 25% (minimum) additional sediment capacity to ensure long-term performance and reduce maintenance costs.*

D. Storm Water Quality Modeling

Since it was not economically feasible to sample and monitor the quality of all water bodies in the watershed, computer models were necessary to estimate the pollutant constituent loadings attributed to storm water runoff from a planning perspective.

The United States Geologic Survey (USGS) Survey Report 88-191 methodology was used to estimate pollutant loadings and water quality impacts from rural agricultural practices and urban land uses. The USGS Survey Report 88-191 is a linear regression method for estimating storm water runoff pollutant loads, volumes, pollutant mean concentrations, and mean seasonal or annual pollutant loads. Two explanatory variables are used in the USGS regression models: (1) the physical and land use characteristics for the individual outfall catchment areas, and (2) the climatic characteristics for the Nine Springs Watershed Area. This methodology development includes thirty-four regression models of storm-runoff constituent loads and storm-runoff volumes; and 31 models of storm-runoff mean concentrations. Ten models of mean seasonal or mean annual constituent loads were developed by analyzing long-term storm-rainfall records using at-site linear regression models. Three statistically different regions of the United States were delineated on the basis of mean annual rainfall to improve linear regression models where adequate data was available. Multiple regression analysis, including ordinary least squares and generalized least squares were used to determine the optimal linear regression models. These developed models can be used to estimate storm-runoff constituent loads, storm-runoff volumes, storm-runoff mean concentrations of constituents, and mean seasonal or mean annual constituent loads at gaged and ungaged watersheds. The most significant explanatory variables in all linear regression models were storm rainfall and total contributing drainage area. Impervious area, land use, and mean climatic characteristics were also significant explanatory variables in some of the linear regression models.

The Agricultural Non-Point Source Pollution Model (AGNPS) was also used to estimate pollutant loadings and water quality impacts from agricultural areas. The AGNPS model is a single-event computer model developed by the U.S. Department of Agriculture, Agriculture Research Center. An SCS-Version 4.0 was developed to simulate sediment and nutrient transport from agricultural watersheds. It can compare the effects of implementing various conservation alternatives within the watershed. The basic components of the model are hydrology, erosion, sediment transport, nutrient and chemical oxygen demand. The model is based on a square grid (cell) geometric representation of the watershed. Each cell homogeneously represents the landscape within the respective grid cell boundary (e.g., only a single run-off curve number and set of Universal

Soil Loss Equation (USLE) parameters are permitted for any individual cell). The respective physical or chemical constituents are routed from its point of origin with a cell using logical hydrologic processes to its storm event destination. This destination may be either deposition within the stream channel system or to the outlet of the watershed.

The Source Loading and Management Model (SLAMM) was used to model water quality impacts for urban development and best management practice improvements in the watershed. SLAMM is an urban nonpoint source water quality model that was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality. SLAMM is strongly based on actual field observations, with minimal reliance on theoretical processes that have not been adequately documented or confirmed in the field. SLAMM provides a better understanding of sources of urban runoff pollutants and their control. Special emphasis has been placed on small storm hydrology and particulate wash off. SLAMM incorporates unique process descriptions to more accurately predict sources of runoff pollutants and flows for the storms of most interest in storm water quality analysis. SLAMM has evolved to include a variety of source area and end of pipe best management controls and the ability to predict the concentrations and loadings of many different pollutants from a large number of potential source areas.

SLAMM calculates mass balances for both particulate and dissolved pollutants and runoff flow volumes for different development characteristics and rainfalls, and uses many different combinations of common urban runoff best management control practices. SLAMM calculates pollutant loadings to receiving waters on an annual basis. The model generates the pollutant loadings based on small storm hydrology using the same runoff curve numbers generated by SCS TR-55 methodology. The runoff curve numbers (correspond to a pollutant coefficient provided in pounds of pollutant per acre of land per year) for eight different pollutant constituents based on research results of storm water sampling in discrete sites within the City of Milwaukee and City of Madison. SLAMM is capable of approximating the effect of land use changes and implementing best management practices.

A number of other storm water quality models were evaluated during the model selection process. Among the models evaluated were: P-8 Urban Catchment Model, WASP, and Walker Pond Net Model. SLAMM Model was chosen because of its small storm hydrology features and ability to compare different best management practice alternatives for various subwatersheds.

Pollutant loading estimates were developed based on the USGS Survey Report 88-191 for rural and urban pollutant loading estimates, AGNPS Model for rural pollutant loading estimates, and the SLAMM Model for urban pollutant loading estimates. The SLAMM Model was used to analyze a variety of source area and outfall control practices (infiltration practices, wet detention ponds, street cleaning, catch basin cleaning, and grass swales) for watershed pollutant reduction discharges. Detailed water quality calculations have been placed in an appendix under separate cover which is available for reference by those who desire to review them. *Summary of water quality assessments are provided in Section IX.*

Storm Water Quantity/Quality Assessment

IX. STORM WATER QUANTITY/QUALITY ASSESSMENT

A. Land Use Analysis

For the purposes of this plan, land use in the Nine Springs Neighborhood Storm Water Management Planning Area was divided into ten classes: Low Density Residential, Medium Density Residential, High Density Residential, Business, Industrial, Commercial, Agriculture, Open Space/Park Conservancy, Woods, and Wetlands. Existing and proposed future land uses were determined by field vegetation and cover mapping, visual observations, aerial photographs and Nine Springs Neighborhood Land Use Plan Maps.

Projected land use tables present the existing land use conditions and proposed future land use conditions for respective subareas within subwatersheds. Map of Subwatersheds and Map of Subareas are provided in Appendix B - Map #3. Each land use category under existing and proposed future conditions is provided as a percentage of the total subarea acreage. The percent change from existing condition to future condition is listed to indicate proposed future development pursuant to the Nine Springs Neighborhood Land Use Plan. Tables that depict 0% change from existing condition to future land use condition indicate that the subarea is either at ultimate development or is undeveloped agricultural land located outside of Nine Springs Neighborhood mapped land use limits.

Composite runoff curve numbers for respective land uses were determined using TR-55 methodology. Runoff curve numbers change based on changes to land use from existing condition to future condition where applicable. Changes in land use and increases in runoff curve number will generally mean a corresponding increase in the peak storm water runoff rate and total storm water runoff volume.

B. Hydrologic/Hydraulic Runoff Analysis

Hydrologic/Hydraulic Storm Water Runoff Water Quantity Analysis Tables present peak runoff rates in cubic feet per second (cfs) and total runoff volume in acre-feet (ac-ft) for respective subareas within subwatersheds. TR-55 methodology was used to model and compute this data. Peak runoff rates and total runoff volume is provided for existing and future land use conditions. Tables that depict existing and future land use conditions on one table indicate that the subarea is either at ultimate development or is undeveloped agricultural land located outside of Nine Springs Neighborhood mapped land use boundary limits. These tables indicate either an increase or decrease in storm water runoff rates and volumes due to changes in land use activities.

C. Water Quality Analysis Pollutant Loading Summary

Water Quality Analysis Pollutant Loading Summary Tables present annual pollutant loading and annual pollutant loadings per acre for total suspended solids (sediment), phosphorus, copper, lead and zinc. Pollutant loads were determined using the USGS Survey Report 88-191, Agricultural Non-Point Source Model (AGNPS), and Source Loading and Management Model (SLAMM) methodologies. Pollutant loading data is provided for existing and future land use conditions. Tables that depict existing and future land use conditions on one table indicate that the subarea is either at ultimate development or is undeveloped agricultural land located outside of Nine Springs Neighborhood mapped land use limits. These tables indicate increases in pollutant loadings based on projected land use changes. Tables that depict zero loadings for zinc, copper and lead indicate that the subarea is primarily agricultural land use, since zinc, copper, lead and other heavy metals originate from streets and parking lots typical of urban land uses.

D. Runoff Analysis Summary After Storm Water Quantity Management Practices

Runoff Analysis Summary after Storm Water Quantity Management Practices Tables present the future condition land use after implementation of recommended water quantity control management recommendations. These tables also indicate the wet detention basin analysis recommended storage requirements. Maps #3 and #4 in Appendix B depict subwatersheds, individual subareas, and recommended structural storm water quantity controls. The percent change from existing condition column is expressed as the increase (or decrease) in peak runoff rate and total runoff volume of future land use conditions over existing land use conditions and does not account for the recommended best management practices. The percent change from future land use condition column is expressed as the decrease in either the existing or future land use condition runoff characteristics considering the effects of the recommended storm water best management practices. The effect of implementing the recommended storm water management practices is quite apparent. Tables that depict 0% change from existing condition indicate that the respective subarea is either at ultimate development or is undeveloped agricultural land located outside of Nine Springs Neighborhood mapped land use limits. Tables that depict 0% change from future land use condition indicate that no storm water quantity practices are recommended within that respective subarea.

E. Pollutant Loading Summary Analysis After Storm Water Quality Management Practices

Pollutant Loading Summary Analysis after Storm Water Quality Management Practices Tables present the future condition land use after implementation of water quality control management recommendations. Maps #3 and #4 in Appendix B depict subwatersheds, subareas, and recommended structural storm water quality controls. The percent change from existing condition column is expressed as the increase in pollutant constituent loading of the future land use conditions over existing land use conditions and does not account for the recommended best management practices. Significant pollutant loadings are apparent in some subareas even though there are small increases in peak runoff rates and volumes. This is because of the increased high density residential, commercial, business park, and industrial use and increased presence of motor vehicles. The increase of pollutant loadings will be reduced by the installation of structural controls and enforcement of non-structural controls. The percent change from future condition column is expressed as the decrease in the existing or future condition pollutant loading rates with the recommended best management practices in place. Tables that depict 0% change from existing condition indicate that the respective subarea is either at ultimate development or is undeveloped agricultural land located outside of Nine Springs Neighborhood mapped land use limits. Tables that depict 0% change from future condition indicate that no storm water quality practices are proposed within that respective subarea.

F. Benefit Cost Effectiveness Assessment of Recommended Best Management Practice Controls

BMP Control	Runoff Volume		Suspended Solids		Phosphorus		Zinc		Copper		Lead	
	Ave. % Reduc.	Ave. \$/Lb.	Ave. % Reduc.	Ave. \$/Lb.	Ave. % Reduc.	Ave. \$/Lb.	Ave. % Reduc.	Ave. \$/Lb.	Ave. % Reduc.	Ave. \$/Lb.	Ave. % Reduc.	Ave. \$/Lb.
Agricultural Land Management (100 % Participation)	21	N/A	30	Min.	30	Min.	N/A	N/A	N/A	N/A	N/A	N/A
Wet Detention	58	N/A	87	0.12	64	78	66	80	66	80	66	80
Grass Swales/ Conservancy Buffer Areas	22	N/A	46	Min.	44	Min.	45	Min.	45	Min.	45	Min.
Roof Disconnections	6	N/A	N/A	Min.	N/A	N/A	23	Min.	23	Min.	23	Min.
Street Cleaning	N/A	N/A	14	0.50	N/A	N/A	12	350	12	350	13	350
Catch Basin Sumps and Cleaning	N/A	N/A	14	0.43	N/A	N/A	13	290	13	290	13	280

G. Ranking Assessment of Recommended Best Management Practice Controls

Note: Cost ranks do not include operation and maintenance costs. Cost ranking is based on typical construction costs only.

1 = Highest Rank

6 = Lowest Rank

Runoff Volume		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	4	3
Wet Detention	1	5
Dry Detention	2	4
Grass Swales/Conservancy Buffer Areas	3	1
Roof Disconnections	5	2
Street Cleaning	N/A	N/A
Catch Basin Sumps and Cleaning	N/A	N/A

Suspended Solids		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	3	2
Wet Detention	1	6
Dry Detention	4	5
Grass Swales/Conservancy Buffer Areas	2	1
Roof Disconnections	N/A	N/A
Street Cleaning	6	3
Catch Basin Sumps and Cleaning	5	4

Phosphorus		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	3	2
Wet Detention	1	4
Dry Detention	4	3
Grass Swales/Conservancy Buffer Areas	2	1
Roof Disconnections	N/A	N/A
Street Cleaning	N/A	N/A
Catch Basin Sumps and Cleaning	N/A	N/A

Zinc		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	N/A	N/A
Wet Detention	1	4
Dry Detention	3	3
Grass Swales/Conservancy Buffer Areas	2	1
Roof Disconnections	4	2
Street Cleaning	6	5
Catch Basin Sumps and Cleaning	5	6

Copper		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	N/A	N/A
Wet Detention	1	4
Dry Detention	3	3
Grass Swales/Conservancy Buffer Areas	2	1
Roof Disconnections	4	2
Street Cleaning	6	5
Catch Basin Sumps and Cleaning	5	6

Lead		
BMP Control	Benefit Rank	Cost Rank
Agricultural Land Management	N/A	N/A
Wet Detention	1	4
Dry Detention	3	3
Grass Swales/Conservancy Buffer Areas	2	1
Roof Disconnections	4	2
Street Cleaning	6	5
Catch Basin Sumps and Cleaning	5	6

SUBAREA A

**TABLE 1 LAND USE ANALYSIS
SUBAREA A**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	5	16%	250	54%	53%
Woods	40	8.5%	40	8.5%	0%
Open Space/Park/Conservancy	25	5.5%	35	7.5%	2%
Agriculture - Row Crops	145	31%	100	21.5%	-9.5%
Agriculture - Legumes	185	40%	40	8.5%	-31.5%
Agriculture - Hay/Alfalfa	65	14%	0	0%	-100%
Totals	465	100%	465	100%	
Composite Runoff Curve Number	70		71		

**Existing Condition
Table 2 Runoff Analysis Results - $CN \leq 70$
Subarea A
465± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	121	25.6
10	299	56.6
25	395	73.2
100	611	108.9

**Future Condition
Table 3 Runoff Analysis Results
Subarea A
465± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	150	27.1
10	354	59.3
25	468	76.3
100	716	112.4

Existing Condition
Table 4 Pollutant Loading Summary
Water Quality Analysis of Subarea A
465± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	136,700	68	294	0.15
Dissolved Solids	299,800	150	645	0.32
Total Phosphorus	372	0.18	0.80	--
Dissolved Phosphorus	92	0.05	0.20	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 5 Pollutant Loading Summary
Water Quality Analysis of Subarea A
465± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	116,200	58	250	0.12
Dissolved Solids	263,800	132	567	0.28
Total Phosphorus	251	0.13	0.54	--
Dissolved	83	0.04	0.18	--
Zinc	85	0.04	0.18	--
Copper	50	0.02	0.11	--
Lead	72	0.04	0.15	--

Future Condition
Table 6 Structural Quantity/Quality Management Control
Subarea A
Wet Detention Basin Analysis
465± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=71	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	121	150	4.7	4.7
10	299	354	9.5	9.5
25	395	468	12.2	17.4
100	611	716	17.6	35.1

*Storage required above normal static water elevation

Future Condition
Table 7 Runoff Analysis Summary
Subarea A
Analysis After Storm Water Quantity Management Practices
465± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	121	150	24%	-19.3%	-19.3%
10	299	354	18.4%	-15.5%	-15.5%
25	395	468	18.5%	-15.6%	-36.1%
100	611	716	17.2%	-14.7%	-58.2%

Future Condition
Table 8 Pollutant Loading Summary
Water Quality Analysis of Subarea A
Analysis After Storm Water Quality Management Practices
465± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	116,200	250	-15%	-86%
Dissolved Solids	263,800	567	-12%	-68%
Total Phosphorus	251	0.54	-32%	-76%
Dissolved Phosphorus	83	0.18	-10%	-66%
Zinc	85	0.18	100%	-85%
Copper	50	0.11	100%	-62%
Lead	72	0.15	100%	-83%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA B

**TABLE 9 LAND USE ANALYSIS
SUBAREA B**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	33	15.5%	55	25.5%	10%
Woods	35	16.5%	30	14%	-2.5%
Open Space/Park/Conservancy	15	7%	15	7%	0%
Agriculture - Row Crops	62	29%	65	30%	3%
Agriculture - Legumes	50	23%	40	19%	-10%
Agriculture - Hay/Alfalfa	20	9%	10	4.5%	-10%
Totals	215	100%	215	100%	
Composite Runoff Curve Number	70		71		

Existing Condition
Table 10 Runoff Analysis Results - CN_≤70
Subarea B
215± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	56	11.8
10	138	26.2
25	183	33.9
100	283	50.3

Future Condition
Table 11 Runoff Analysis Results
Subarea B
215± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	69	12.5
10	164	27.4
25	216	35.3
100	331	52.0

Existing Condition
Table 12 Pollutant Loading Summary
Water Quality Analysis of Subarea B
215± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	50,025	25	233	0.12
Dissolved Solids	59,900	30	279	0.14
Total Phosphorus	99	0.05	0.46	--
Dissolved Phosphorus	17	0.009	0.08	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 13 Pollutant Loading Summary
Water Quality Analysis of Subarea B
215± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	43,500	22	202	0.10
Dissolved Solids	54,100	27	252	0.13
Total Phosphorus	84	0.042	0.39	--
Dissolved Phosphorus	15	0.007	0.07	--
Zinc	8	0.004	0.03	--
Copper	15	0.008	0.07	--
Lead	30	0.015	0.14	--

Future Condition
Table 14 Structural Quantity/Quality Management Control
Subarea B
Wet Detention Basin Analysis
215± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=71	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	56	69	2.2	2.2
10	138	164	4.4	4.4
25	183	216	5.6	8.1
100	283	331	9.1	17.2

*Storage required above normal static water elevation

Future Condition
Table 15 Runoff Analysis Summary
Subarea B
Analysis After Storm Water Quantity Management Practices
215± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	56	69	23.2%	-18.8%	-18.8%
10	138	164	18.8%	-15.8%	-15.8%
25	183	216	18.0%	-15.3%	-36.1%
100	283	331	17.0%	-14.5%	-58.3%

Future Condition
 Table 16 Pollutant Loading Summary
 Water Quality Analysis of Subarea B
 Analysis After Storm Water Quality Management Practices
 215± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	43,500	202	-13%	-83%
Dissolved Solids	54,100	252	-9.7%	-63%
Total Phosphorus	84	0.39	-15%	-75%
Dissolved Phosphorus	15	0.07	-12%	-63%
Zinc	8	0.03	100%	-83%
Copper	15	0.07	100%	-61%
Lead	30	0.14	100%	-82%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA C

**TABLE 17 LAND USE ANALYSIS
SUBAREA C**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Parks/Open/Conservancy	--	--	5	7%	7%
Woods	6	9%	6	9%	0%
Medium Density Residential	--	--	25	35.5%	35.5%
High Density Residential	--	--	14	20%	20%
Agriculture - Row Crops	29	41%	--	--	-100%
Agriculture - Legumes	5	7%	--	--	-100%
Agriculture - Hay/Alfalfa	10	14.5%	--	--	-100%
Farmstead	20	28.5%	20	28.5%	0%
Totals	70	100%	70	100%	
Composite Runoff Curve Number	72		74		

Existing Condition
Table 18 Runoff Analysis Results - CN_≤70
Subarea C
70± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	25	3.8
10	61	8.5
25	80	11.0
100	124	16.4

Future Condition
Table 19 Runoff Analysis Results
Subarea C
70± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	34	5.0
10	74	10.1
25	97	12.9
100	144	18.6

Existing Condition
Table 20 Pollutant Loading Summary
Water Quality Analysis of Subarea C
70± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	20,100	10	287	0.14
Dissolved Solids	17,400	9	248	0.13
Total Phosphorus	30	0.015	0.42	--
Dissolved Phosphorus	8	0.004	0.11	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 21 Pollutant Loading Summary
Water Quality Analysis of Subarea C
70± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	18,200	9	260	0.13
Dissolved Solids	16,000	8	229	0.11
Total Phosphorus	23	0.012	0.32	--
Dissolved Phosphorus	7	0.003	0.10	--
Zinc	15	0.008	0.21	--
Copper	5	0.003	0.07	--
Lead	15	0.008	0.21	--

Future Condition
Table 22 Structural Quantity/Quality Management Control
Subarea C
Wet Detention Basin Analysis
70± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=74	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	25	34	1.0	1.0
10	61	74	1.7	1.7
25	80	97	2.2	3.0
100	124	144	2.8	5.7

*Storage required above normal static water elevation

Future Condition
Table 23 Runoff Analysis Summary
Subarea C
Analysis After Storm Water Quantity Management Practices
70± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	25	34	36%	-26.5%	-26.5%
10	61	74	21.3%	-17.6%	-17.6%
25	80	97	21.2%	-17.5%	-37.1%
100	124	144	16.1%	-13.9%	-57.6%

Future Condition
Table 24 Pollutant Loading Summary
Water Quality Analysis of Subarea C
Analysis After Storm Water Quality Management Practices
70± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	18,200	260	-9.5%	-84%
Dissolved Solids	16,000	229	-8%	-62%
Total Phosphorus	23	0.32	-23%	-75%
Dissolved Phosphorus	7	0.10	-12.5%	-64%
Zinc	15	0.21	100%	-82%
Copper	5	0.07	100%	-62%
Lead	15	0.21	100%	-82%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA D

**TABLE 25 LAND USE ANALYSIS
SUBAREA D**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	5	2%	5	2%	0%
Wetlands/Forest/Grass/Shrubs	35	14.5%	35	14.5%	0%
Woods	20	8%	20	8%	0%
High Density Residential	—	—	150	61%	150%
Commercial	5	2%	20	8%	6%
Open Space/Park/Conservancy	—	—	15	6.5%	6.5%
Agriculture - Legumes	170	69.5%	—	—	-100%
Agriculture - Pasture	10	4%	—	—	-100%
Totals	245	100%	245	100%	
Composite Runoff Curve Number	67		76		

**Existing Condition
Table 26 Runoff Analysis Results - CN_≤70
Subarea D
245± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	47	11.0
10	133	25.9
25	178	34.1
100	284	51.6

**Future Condition
Table 27 Runoff Analysis Results
Subarea D
245± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	111	19.4
10	243	38.6
25	312	48.4
100	456	69.0

Existing Condition
Table 28 Pollutant Loading Summary
Water Quality Analysis of Subarea D
245± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	57,700	29	235	0.12
Dissolved Solids	75,250	38	307	0.15
Total Phosphorus	120	0.06	0.49	--
Dissolved Phosphorus	19	0.0097	0.077	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 29 Pollutant Loading Summary
Water Quality Analysis of Subarea D
245± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	83,300	42	340	0.17
Dissolved Solids	94,500	47	386	0.19
Total Phosphorus	186	0.093	0.76	--
Dissolved Phosphorus	27	0.013	0.11	--
Zinc	115	0.032	0.47	--
Copper	32	0.016	0.13	--
Lead	110	0.029	0.45	--

Future Condition
Table 30 Structural Quantity/Quality Management Control
Subarea D
Wet Detention Basin Analysis
245± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=76	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	47	111	6.0	6.0
10	133	243	10.0	10.0
25	178	312	12.1	14.9
100	284	456	16.1	26.5

*Storage required above normal static water elevation

Future Condition
Table 31 Runoff Analysis Summary
Subarea D
Analysis After Storm Water Quantity Management Practices
245± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	47	111	136%	-57.6%	-57.6%
10	133	243	82%	-45.3%	-45.3%
25	178	312	75.2%	-42.9%	-57.4%
100	284	456	60.6%	-37.7%	-70.8%

Future Condition
Table 32 Pollutant Loading Summary
Water Quality Analysis of Subarea D
Analysis After Storm Water Quality Management Practices
245± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	83,300	340	44%	-88%
Dissolved Solids	94,500	386	26%	-64%
Total Phosphorus	186	0.76	55%	-78%
Dissolved Phosphorus	27	0.013	42%	-68%
Zinc	115	0.47	100%	-86%
Copper	32	0.13	100%	-65%
Lead	110	0.45	100%	-84%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA E

**TABLE 33 LAND USE ANALYSIS
SUBAREA E**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	20	7.5%	122	45%	25%
Open Space/Park/Conservancy	80	29%	10	3.5%	-25.5%
Medium Density Residential	—	—	121	45%	45%
Wetlands	2	1%	2	1%	0%
Woods	20	7.5%	15	5.5%	2%
Agriculture - Row Crops	108	40%	—	—	-100%
Agriculture - Legumes	20	7.5%	—	—	-100%
Agriculture - Hay/Alfalfa	20	7.5%	—	—	-100%
Totals	270	100%	270	100%	
Composite Runoff Curve Number	60		71		

**Existing Condition
Table 34 Runoff Analysis Results - $CN \leq 70$
Subarea E
270± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	18	6.7
10	78	19.3
25	115	26.8
100	198	43.2

**Future Condition
Table 35 Runoff Analysis Results
Subarea E
270± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	76	15.7
10	184	34.4
25	242	44.3
100	366	65.2

Existing Condition
Table 36 Pollutant Loading Summary
Water Quality Analysis of Subarea E
270± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	64,600	32	239	0.12
Dissolved Solids	90,180	45	334	0.17
Total Phosphorus	139	0.67	0.51	0.002
Dissolved Phosphorus	21	0.01	0.08	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 37 Pollutant Loading Summary
Water Quality Analysis of Subarea E
270± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	51,300	26	190	0.10
Dissolved Solids	73,950	37	274	0.14
Total Phosphorus	121	0.060	0.45	--
Dissolved Phosphorus	17	0.008	0.06	--
Zinc	63	0.031	0.23	--
Copper	21	0.010	0.08	--
Lead	56	0.028	0.21	--

Future Condition
Table 38 Structural Quantity/Quality Management Control
Subarea E
Wet Detention Basin Analysis
270± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=71	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	18	76	6.7	6.7
10	78	184	10.6	10.6
25	115	242	12.7	16.2
100	198	366	17.0	29.0

*Storage required above normal static water elevation

Future Condition
Table 39 Runoff Analysis Summary
Subarea E
Analysis After Storm Water Quantity Management Practices
270± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	18	76	322%	-76.3%	-76.3%
10	78	184	136%	-57.6%	-57.6%
25	115	242	110%	-52.5%	-67.7%
100	198	366	84.8%	-45.9%	-78.7%

Future Condition
Table 40 Pollutant Loading Summary
Water Quality Analysis of Subarea E
Analysis After Storm Water Quality Management Practices
270± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	51,300	190	-21%	-82%
Dissolved Solids	73,950	274	-18%	-63%
Phosphorus	121	0.45	-13%	-74%
Dissolved Phosphorus	17	0.06	-19%	-65%
Zinc	63	0.23	100%	-82%
Copper	21	0.08	100%	-62%
Lead	56	0.21	100%	-80%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA F

**TABLE 41 LAND USE ANALYSIS
SUBAREA F**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Medium Density Residential	—	—	158	83%	100%
Woods	2	1%	—	—	-100%
Commercial/Industrial	10	5.5%	12	6.5%	1%
Parks/Open/Conservancy	—	—	20	10.5%	100%
Farmstead	3	1.5%	—	—	-100%
Agriculture - Fallow	25	13%	—	—	-100%
Agriculture - Row Crops	150	79%	—	—	-100%
Totals	190	100%	190	100%	
Composite Runoff Curve Number	77		74		

**Existing Condition
Table 42 Runoff Analysis Results - CN_≤70
Subarea F
190± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	68	10.5
10	164	23.1
25	216	29.9
100	337	44.5

**Future Condition
Table 43 Runoff Analysis Results
Subarea F
190± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	117	13.5
10	256	27.5
25	331	35.0
100	490	50.3

Existing Condition
Table 44 Pollutant Loading Summary
Water Quality Analysis of Subarea F
190± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	44,000	22	232	0.12
Dissolved Solids	48,800	24	257	0.13
Total Phosphorus	95	0.047	0.50	--
Dissolved Phosphorus	15	0.008	0.08	--
Zinc	--	--	--	--
Copper	--	--	--	--
Lead	--	--	--	--

Future Condition
Table 45 Pollutant Loading Summary
Water Quality Analysis of Subarea F
190± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	37,000	18	195	0.09
Dissolved Solids	42,450	21	223	0.11
Total Phosphorus	84	0.042	0.44	--
Dissolved Phosphorus	13	0.006	0.07	--
Zinc	42	0.021	0.22	--
Copper	13	0.007	0.07	--
Lead	38	0.019	0.20	--

Future Condition
Table 46 Structural Quantity/Quality Management Control
Subarea F
Wet Detention Basin Analysis
190± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=74	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	68	117	3.3	3.3
10	164	256	6.3	6.3
25	216	331	7.8	9.7
100	337	490	10.7	18.0

*Storage required above normal static water elevation

Future Condition
Table 47 Runoff Analysis Summary
Subarea F
Analysis After Storm Water Quantity Management Practices
190± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	68	117	72.0%	-41.9%	-41.9%
10	164	256	56.1%	-35.9%	-35.9%
25	216	331	53.2%	-34.7%	-50.4%
100	337	490	45.4%	-31.2%	-66.5%

Future Condition
Table 48 Pollutant Loading Summary
Water Quality Analysis of Subarea F
Analysis After Storm Water Quality Management Practices
190± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	37,000	18	-16%	-85%
Dissolved Solids	42,450	21	-13%	-68%
Total Phosphorus	84	0.042	-11%	-77%
Dissolved Phosphorus	13	0.006	-13%	-69%
Zinc	42	0.021	100%	-83%
Copper	13	0.007	100%	-64%
Lead	38	0.019	100%	-81%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA G

**TABLE 49 LAND USE ANALYSIS
SUBAREA G**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Business Park	23	66%	32	91.5%	25.5%
Open Space/Park/Conservancy	--	--	3	--	100%
Agriculture - Fallow	5	14%	--	8.5%	-100%
Agriculture - Legumes	7	20%	--	--	-100%
Totals	35	100%	35	100%	
Composite Runoff Curve Number	75		86		

**Existing Condition
Table 50 Runoff Analysis Results - CN_≤70
Subarea G
35± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	16	1.9
10	38	4.3
25	51	5.5
100	78	8.2

**Future Condition
Table 51 Runoff Analysis Results
Subarea G
35± AC**

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	45	4.6
10	79	8.0
25	95	9.6
100	128	12.9

Existing Condition
Table 52 Pollutant Loading Summary
Water Quality Analysis of Subarea G
35± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	14,100	7	403	0.20
Dissolved Solids	7,880	4	225	0.11
Total Phosphorus	19	0.009	0.54	--
Dissolved Phosphorus	6	0.003	0.17	--
Zinc	15	0.0075	0.43	--
Copper	4	0.0018	0.11	--
Lead	15	0.0075	0.43	--

Future Condition
Table 53 Pollutant Loading Summary
Water Quality Analysis of Subarea G
35± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	22,575	11.3	645	0.32
Dissolved Solids	11,600	5.8	331	0.17
Total Phosphorus	41	0.020	1.16	--
Dissolved Phosphorus	11	0.006	0.31	--
Zinc	77	0.038	2.2	--
Copper	17	0.008	0.50	--
Lead	74	0.037	2.1	--

Future Condition
Table 54 Structural Quantity/Quality Management Control
Subarea G
Wet Detention Basin Analysis
35± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=86	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	16	45	1.6	1.6
10	38	79	2.3	2.3
25	51	95	2.5	3.1
100	78	128	3.1	4.9

*Storage required above normal static water elevation

Future Condition
Table 55 Runoff Analysis Summary
Subarea G
Analysis After Storm Water Quantity Management Practices
35± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	16	45	181%	-64.4%	-64.4%
10	38	79	108%	-51.9%	-51.9%
25	51	95	86.3%	-46.3%	-60.0%
100	78	128	64.1%	-39.1%	-70.3%

Future Condition
Table 56 Pollutant Loading Summary
Water Quality Analysis of Subarea G
Analysis After Storm Water Quality Management Practices
35± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	22,575	645	60%	-82%
Dissolved Solids	11,600	331	47%	-64%
Total Phosphorus	41	1.16	116%	-73%
Dissolved Phosphorus	11	0.31	83%	-65%
Zinc	77	2.2	413%	-83%
Copper	17	0.50	325%	-61%
Lead	74	2.1	413%	-80%

*Compared to Future Conditions without Recommended Management Practices.

SUBAREA H

**TABLE 57 LAND USE ANALYSIS
SUBAREA H**

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	5	2%	5	2%	0%
Woods	7	3%	7	3%	0%
Medium Density Residential	--	--	10	4.5%	100%
High Density Residential	--	--	15	7.5%	100%
Business Park	--	--	143	66.5%	100%
Forested Wetlands	15	7%	15	7%	0%
Open/Parks/Conservancy	--	--	20	9.5%	100%
Agriculture - Legumes	180	84%	--	--	-100%
Agriculture - Sod Farm	8	4%	--	--	-100%
Totals	215	100%	215	100%	
Composite Runoff Curve Number	70		81		

Existing Condition
Table 58 Runoff Analysis Results - $CN \leq 70$
Subarea H
215± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	50	11.8
10	123	26.2
25	162	33.9
100	250	50.3

Future Condition
Table 59 Runoff Analysis Results
Subarea H
215± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	122	22.2
10	237	41.0
25	294	50.3
100	405	69.5

Existing Condition
Table 60 Pollutant Loading Summary
Water Quality Analysis of Subarea H
215± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	50,000	25	233	0.12
Dissolved Solids	59,800	30	278	0.14
Total Phosphorus	100	0.50	0.46	0.002
Dissolved Phosphorus	17	0.008	0.08	--
Zinc	75	0.037	0.35	--
Copper	15	0.008	0.07	--
Lead	67	0.033	0.31	--

Future Condition
Table 61 Pollutant Loading Summary
Water Quality Analysis of Subarea H
215± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	106,400	53	495	0.25
Dissolved Solids	92,690	46	431	0.21
Total Phosphorus	204	0.10	0.95	--
Dissolved Phosphorus	30	0.015	0.14	--
Zinc	247	0.12	1.15	--
Copper	23	0.011	0.107	--
Lead	247	0.12	1.15	--

Future Condition
Table 62 Structural Quantity/Quality Management Control
Subarea H
Wet Detention Basin Analysis
215± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=81	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	50	122	7.0	7.0
10	123	237	11.0	11.0
25	162	294	13.0	15.7
100	250	405	16.3	26.2

*Storage required above normal static water elevation

Future Condition
Table 63 Runoff Analysis Summary
Subarea H
Analysis After Storm Water Quantity Management Practices
215± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	50	122	144%	-59.0%	-59.0%
10	123	237	92.7%	-48.1%	-48.1%
25	162	294	81.5%	-44.9%	-58.2%
100	250	405	62.0%	-38.3%	-69.6%

Future Condition
Table 64 Pollutant Loading Summary
Water Quality Analysis of Subarea H
Analysis After Storm Water Quality Management Practices
215± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	106,400	495	113%	-83%
Dissolved Solids	92,690	431	55%	-65%
Total Phosphorus	204	0.95	104%	-74%
Dissolved Phosphorus	30	0.14	76%	-66%
Zinc	247	1.15	229%	-84%
Copper	23	0.107	53%	-63%
Lead	247	1.15	268%	-82%

*Compared to Future Conditions without Recommended Management Practices.

SUMMARY

STORM WATER QUANTITY/QUALITY ASSESSMENT
ENTIRE WATERSHED (SUBAREAS A-H)

SUMMARY
TABLE 65 LAND USE ANALYSIS
ENTIRE WATERSHED
1705± AC

Land Use	Existing Condition		Future Condition		
	Acres	% of Subarea	Acres	% of Subarea	Changes from Exist. Condition %
Low Density Residential	68	4%	437	26%	22%
Medium Density Residential	—	—	314	18.5%	100%
High Density Residential	—	—	179	10.5%	100%
Commercial/Industrial	15	1%	32	2%	1%
Business Park	23	1.5%	143	8.5%	7%
Woods	130	7.5%	118	7%	-0.50%
Open Space/Park Conservancy	120	7%	123	7.5%	0.50%
Wetlands/Forest/Grass/Shrubs	52	3%	52	3%	0%
Farmstead	23	1.5%	20	1.5%	0%
Agriculture - Row Crops	494	29%	165	10%	-19%
Agriculture - Legumes	617	36%	80	5%	-31%
Agriculture - Hay/Alfalfa	115	6.5%	10	0.50%	-6%
Agriculture - Pasture	10	0.50%	—	—	-0.50%
Agriculture - Fallow	30	2%	—	—	-2%
Agriculture - Sod Farm	8	0.50%	—	—	-0.50%
Totals	1705	100%	1705	100%	
Composite Runoff Curve Number	69		74		

Summary
Existing Condition
Table 66 Runoff Analysis Results - $CN \leq 70$
Entire Watershed
1705± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	401	83.1
10	1034	190.1
25	1380	248.3
100	2165	373.4

Summary
Future Condition
Table 67 Runoff Analysis Results
Entire Watershed
1705± AC

Storm Frequency	Peak Runoff Rate (CFS)	Total Runoff Volume (AC-Ft.)
2	724	120
10	1591	246.3
25	2055	312.1
100	3036	449.9

Summary
Existing Condition
Table 68 Pollutant Loading Summary
Water Quality Analysis of Entire Watershed
1705± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	387,225	193	227	0.11
Dissolved Solids	659,010	329	386	0.19
Total Phosphorus	974	0.49	0.57	--
Dissolved Phosphorus	195	0.097	0.11	--
Zinc	90	0.045	0.05	--
Copper	19	0.009	0.01	--
Lead	82	0.041	0.05	--

Summary
Future Condition
Table 69 Pollutant Loading Summary
Water Quality Analysis of Entire Watershed
1705± AC

Pollutant	Annual Loading		Annual Loading Per Acre	
	Lbs/Yr	Tons/Yr	Lbs/Ac/Yr	Ton/Ac/Yr
Suspended Solids	478,475	239	281	0.14
Dissolved Solids	649,090	324	381	0.19
Total Phosphorus	994	0.50	0.58	--
Dissolved Phosphorus	203	0.10	0.12	--
Zinc	652	0.33	0.38	--
Copper	176	0.09	0.10	--
Lead	642	0.32	0.38	--

Summary
Future Condition
Table 70 Structural Quantity/Quality Management Control
Entire Watershed
Wet Detention Basin Analysis
1705± AC

Storm Frequency	Exist. Cond. Peak Runoff Rate (CFS) CN≤70	Future Cond. Peak Runoff Rate (CFS) CN=74	Detention* Storage at Pre vs. Post Discharge (AC-FT)	Detention* Storage at ≤Pre-10 Yr. Discharge (AC-FT)
2	401	724	32.5	32.5
10	1034	1591	55.8	55.8
25	1380	2055	68.1	88.1
100	2165	3036	92.7	162.6

*Storage required above normal static water elevation

Summary
Future Condition
Table 71 Runoff Analysis Summary
Entire Watershed
Analysis After Storm Water Quantity Management Practices
1705± AC

Storm Frequency	Exist. Peak Runoff Rate CN≤70 (CFS)	Future Peak Runoff Rate (CFS)	% Change from Exist. Condition	% Change from Future Condition @ Pre vs. Post	% Change from Future Conditions @ Pre-10 Yr.
2	401	724	80.5%	-44.6%	-44.6%
10	1034	1591	53.9%	-35.0%	-35.0%
25	1380	2055	48.9%	-32.8%	-49.7%
100	2165	3036	40.2%	-28.7%	-65.9%

Summary
Future Condition
Table 72 Pollutant Loading Summary
Water Quality Analysis of Entire Watershed
Analysis After Storm Water Quality Management Practices
1705± AC

Pollutant	Annual Loading (lbs/year)	Annual Loading (lbs/AC/yr)	% Change from Exist. Condition	% Change from Future Condition*
Suspended Solids	478,475	281	23.6%	-84%
Dissolved Solids	649,090	381	-1.50%	-65%
Total Phosphorus	994	0.58	2.05%	-75%
Dissolved Phosphorus	203	0.12	4.1%	-66%
Zinc	652	0.38	624%	-83%
Copper	176	0.10	826%	-62%
Lead	642	0.38	683%	-82%

*Compared to Future Conditions without Recommended Management Practices.

Best Management Practices

X. BEST MANAGEMENT PRACTICES

A. General

Best management practices (BMPs) recommended in this plan for the Nine Springs Neighborhood are measures intended to reduce or mitigate water quantity and water quality concerns to the maximum extent practical. Certain measures can help reduce impacts, but no BMP will totally mitigate past problems, agricultural practices and proposed urban development. There are many ways to approach BMP site design and it is most easily done within developing areas.

Rural and developing areas allow for unique opportunities to incorporate BMPs into site design. The BMPs can be incorporated into natural areas serving as open spaces for community enjoyment. This idea can be expanded into a fingerprinting concept that requires developments to duplicate BMPs to some extent at each site. The fingerprinting requirements ensure a minimum set of controls at each site.

Another technique is for the City, County or WIDNR to purchase land next to a water resource and create a buffer strip around the area and construct BMPs. In certain cases, this may be the only way to protect a sensitive water body from further degradation, even with several BMPs in place.

Water Quality and Flood Control Best Management Practices can be categorized as either structural or non-structural controls. Structural best management controls include wet detention-sedimentation basins, constructed wetlands, infiltration basins, infiltration trenches, dry detention basins, sump storm sewer inlets, riprap, gabions, construction of grassed channels and drainageways, silt fence, stone weeper berms, and straw bales. Non-structural controls include street sweeping, catch basin cleaning, public education and information program, salt/sand/deicer use on winter streets, leaf and lawn waste control, pet and farm animal waste control, construction site erosion control regulations and enforcement, storm water management planning education and ordinances, and land use planning. A large percentage of water quantity and quality control benefits can be obtained by using non-structural best management practices rather than using expensive structural best management practices. However, some structural controls must be provided in order to obtain the greatest amount of pollutant reduction and flood control within the Nine Springs Neighborhood Watershed.

We recommend that the following non-structural and structural best management practices be implemented to address pollutant loading and flood control within the Nine Springs Neighborhood watershed.

B. Recommended Structural Best Management Controls

1. Wet Detention Basins

Wet detention basins are the most effective and most commonly used best management practices for flood control, sedimentation control, and control of numerous pollutants found in storm water runoff. They are reliable and attractive systems that help control storm water quality and quantity. They are the most cost effective systems to operate and maintain. These systems consist of a single or multiple permanent pools of water or a combination of a single permanent pool of water with a pretreatment sedimentation area that treats incoming storm water and discharges improved storm water quality to sensitive receiving water bodies and groundwater recharge areas. *Wet detention basins are typically engineered with four to eight feet of standing water, allowing sediments and pollutants to settle out, with a defined sedimentation basin, forebay, and outlet control structure.*

Many studies have shown that wet detention basins consistently remove sediments and pollutants that attach to sediments. Removal rates can vary from 50 to 90 percent, depending on particle sizes and on the design size and shape of the system. Wet detention basins can also control pollutants such as heavy metals, phosphorus, and bacteria, but at lower removal rates than sediments. Pollution control rates can also vary depending on the construction of the system, but in general the following approximate rates apply:

<u>Pollutant</u>	<u>Percent Reduction</u>
Suspended Solids (sediment)	50-90%
Phosphorus	12-79%
Nitrogen	6-62%
Chemical Oxygen Demand (COD)	7-76%
Lead	8-84%
Copper	7-65%
Zinc	13-87%

If wet detention basins are properly designed, engineered, and constructed they can also be an attractive environmental asset for wildlife, humans, and property value appreciation. The systems can be integrated with green space areas to provide park-like settings, while also controlling sediments and storm water pollutants from being discharged to the E-Way, wetlands, creeks, Yahara River, and lakes.

Negative impacts of wet detention basins are very limited concerning water resources and include potential downstream warming from thermal discharges. A typical public concern is child safety near the standing pools of water. Another common concern is the long-term maintenance requirement associated with these systems. These negative impacts and concerns can be mitigated with proper system engineering design and construction.

Sediment settling is the most important function of the wet detention basin BMP which makes it the highest priority recommendation as concluded by the study review analysis. Wet detention basin design considerations should include the following:

- Soil Type
- Slope of the System Banks
- Depth to Groundwater
- Depth to Bedrock
- Pretreatment and Control of Sediment Input
- Size and Depth of the System
- Flood Control Design
- Hydrological and Hydraulic Impacts Downstream and Upstream of the System
- Maintenance

Due to the size of the Nine Springs Neighborhood Watershed, more than one wet detention basin will be necessary to obtain maximum sediment and pollutant removal goals and also control flooding. *We recommend that several wet detention basins be designed and constructed over time as financial resources and private developments permit. The approximate location of the recommended wet detention basin/sedimentation basins are illustrated in Appendix B - Map #4.* The highest priority wet detention/sedimentation basin locations are those immediately upstream of E-Way, creeks, and wetlands. *Designing and constructing several interconnected wet detention basins and prairie grass vegetation buffer areas will provide a multi-stage storm water treatment train system to mitigate further flooding, sediment, and pollutant discharges to the E-Way, wetlands, creeks, Yahara River, and lakes.* The siting location of these wet detention basins is very critical for construction, operation and maintenance, public enjoyment, recreation, park land use, environmental protection, and flood control. The wet detention/sedimentation basins shown on the maps are intended to be implemented by private developers as part of their urbanization and development plans in these areas. *As discussed in this plan, we recommend that a storm water management plan and ordinance be implemented to require developers to contribute their fair share to reduce sedimentation,*

mitigate water quality degradation, and reduce increased water quantity discharges within the Nine Springs Neighborhood Watershed. The financial burden on the City of Fitchburg within this watershed can be greatly reduced and the benefits greatly increased by partnering with private and public entities.

Extended wet detention basins are effective in reducing post-development peak discharge rates to the designed pre-development levels for the design storms specified. The optimum level of flood control is achieved when multiple storms are controlled. The recommended wet detention basins are intended to manage both smaller and larger floods that contribute to channel erosion and sedimentation loading problems. Peak-shaving design with the wet-detention basins will reduce the extent of downstream channel flooding and erosion when geared to control the two-, five- and ten-year storms. Early research demonstrated that bank full discharges occurring on average every 1.5 to 2 years, control the shape and form of natural channels. *We recommend that all municipalities within the Watershed adopt storm water detention basin policies that require the post-development peak discharges for all storms, including the 2-year storm, be controlled at or less than pre-development levels for flood and sediment control. Storm events equal to or greater than the 10-year post-development event should be controlled at the 10-year pre-development discharge rate wherever feasible and practical.*

Storm water erosion can only be controlled when both the magnitude and frequency of the post-development floods are adequately managed by detention basin storage. After a watershed is developed, small intense storms can dramatically increase the frequency in which two-year bank full discharges occur. The increased number of bank full floods, in turn, increases the probability of downstream bank and channel erosion and subsequent sediment loading.

We recommend a ten to fifteen year sediment clean-out cycle for wet detention basins. This schedule may need to be revised based on special site design and field observations. Extra storage in the lower stage can be provided to accommodate additional sediment deposition. To reduce removal costs, we recommend provisions be made for on-site disposal or the City should plan for use of the accumulated sediment at some future date.

2. Constructed Wetlands

We recommend that constructed wetlands in conjunction with wet detention basins be implemented, if feasible, as a BMP to control and

pre-treat storm water runoff. The concept of constructed wetlands is not new. Point source dischargers have used these treatment structures for years. Constructed storm water wetlands are shallow pools that enhance growing conditions for marsh plants and native prairie grasses to maximize sediment and pollutant removal. These constructed wetlands differ from naturally created wetlands since they do not totally reproduce and mimic the ecological diversity found in naturally created wetlands.

Constructed wetlands and native prairie grasses can effectively remove sediments and most pollutants from storm water runoff. This takes place by the diverse treatment mechanisms of sedimentation, infiltration, chemical precipitation, absorption, microbial interactions, and uptake by vegetation.

Pollution control rates will vary depending on design, construction methods, and the vegetation associated with the wetland. In general, constructed wetlands and native prairie grasses can be expected to provide the following approximate removal efficiencies:

<u>Pollutant</u>	<u>Percent Reduction</u>
Suspended Solids (sediments)	14-98%
Phosphorus	0-97%
Nitrogen	25-30%
COD	22-27%
Iron	43-92%
Lead	68-82%
Zinc	34-50%

Please keep in mind that constructed wetlands are designed for pollutant removal and they differ from natural wetlands in many ways. The most obvious difference is that constructed wetlands may not fulfill the requirements associated with wetland mitigation action since they are not designed to replace existing wetlands.

We recommend the design and construction of wetland marshes and native prairie grasses be considered to create the lower stage of proposed multi-stage wet-detention basins to help remove soluble pollutants that cannot be removed by conventional water column settling.

Constructed wetlands can provide groundwater recharge, wildlife habitat and hide unsightly debris and sediment deposits that frequently accumulate at detention basin inlets and outlets.

Design considerations for constructed wetlands and native prairie grasses can be numerous. Site selection, wet surface area, water depth, wetland plantings, and maintenance all play important roles. We do not recommend that constructed wetlands be located within natural wetland areas. The wetland area should be adjusted so the average annual watershed loading to the constructed wetlands does not exceed 45 pounds of phosphorus or 225 pounds of nitrogen for the surface area of wetland. Water depths of 6-12 inches are recommended for optimal wetland growth. *The wetland should be planted with native species suited to that environment with native prairie grasses in upland areas adjacent to wetland plantings and wet detention basin upper stage areas.* By effectively controlling soluble nutrients such as nitrogen and ortho-phosphorus, eutrophication of the water resources can be mitigated.

Constructed wetlands do have some negative impacts on land and water resource such as the following:

- Possible impact on the wetland biota from trace metal uptake
- Discharges are warmer than inflows
- Possible takeover by invasive aquatic nuisance plants such as purple loosestrife, and cattails
- Construction may adversely impact existing wetlands or forest areas
- Potential safety hazards
- Occasional nuisance problems (odor, algae, debris)
- Eventual need for costly sediment removal and wetland restoration

We recommend that objectives for wet detention basins and wetlands be considered at every potential site and everyone should be aware that final design may never achieve 100% of all intended objectives.

However, combined wet-detention basins, constructed wetlands, and native prairie grasses are unique since they can truly be a multi-purpose BMP, by providing storm water management, pollutant removal, and landscaping/habitat improvement to the maximum extent practical.

3. Infiltration Basins / Dry Detention Basins

Infiltration basins / dry detention basins are large open depressions that store incoming storm water runoff while percolation occurs through the bottom and sides. Soils, slopes, geology, hydrogeology, and drainage area restrict the use of the basins. Infiltrating storm water allows groundwater recharge to maintain spring and creek baseflow, and colder creek temperatures. Infiltrating and dry

detention basins also control flooding and stream bank erosion by reducing runoff.

Infiltration / dry detention basins with native prairie grass vegetation are effective by removing both soluble and fine particulate pollutants found in storm water runoff if site conditions are right. Coarse-grained pollutants should generally be removed before they enter a dry detention basin.

We recommend that infiltration / dry retention basins be considered as a secondary BMP with native prairie grass vegetation, wet detention basins, and constructed wetlands. There may be isolated areas within the watershed where it may be feasible to use infiltration / dry detention basins as the primary BMP. Individual site specific conditions should be thoroughly investigated prior to design and construction of the infiltration/dry detention basin BMP.

The following are some of the negative impacts that can be associated with infiltration / dry detention basins:

- Limited life span
- Maintenance to prevent clogging or sealing of the structure
- Regular mowing
- Raise groundwater table and cause flooding
- Contaminants in storm water could negatively affect groundwater quality

We recommend the following minimum design criteria for infiltration / dry detention basins:

- Area served <50 acres
- Areas <50% impervious
- High seasonal water table > 3 feet below basin
- Percolation rate > 12 hours, < 24 hours
- Depth to bedrock > 5 feet below basin
- Do not locate in groundwater discharge zones or high traffic areas
- Side slopes <3.5:1 for safety and mowing
- Smoothly distribute inflow
- Densely grass basin area with native prairie grasses
- Provide overflow spillway emergency outlet
- Prevent compaction of soils in basin during construction
- Large enough to store snowmelt until spring thaw
- French drain infiltration back-up system to subsurface granular soils
- Provide minimum sedimentation distances to wells, foundations, and septic drain fields
- Minimize soil removal and disturbance during construction

4. Riprap / Gabions / Geotextiles

During our field reconnaissance of the E-Way, Nine Springs Creek, Swan Creek, and drainageways, we observed a large amount of stream bank erosion throughout the watershed. We observed that some of the drainageway and stream buffer zones have been cleared so trees and vegetation do not provide natural stream bank stabilization.

We recommend implementation of a creek restoration program to stabilize the severely eroded sections of Nine Springs Creek and Swan Creek. This restoration can include a reforestation and vegetative planting program, installation of riprap, gabions, and geotextile erosion control measures. Riprap and gabions should only be installed at the hard corners of the creek. Riprap and gabions can be buried in the creek bank and covered with vegetative type plantings so that they aesthetically fit into the natural features of the environment. A properly designed creek bank system can provide both bank stabilization and aquatic habitat benefits. Riprap and gabions need to be properly sized and designed for the creek flow and velocity conditions so they are not transported and displaced downstream during large rainfall events.

We recommend that major drainageways, wetlands, Nine Springs Creek, and Swan Creek be protected with conservancy area native prairie grassed buffer zone adjacent and along these sensitive areas to control erosion, filter out pollutants, and capture sediments.

5. Grassed Channels/Drainageways/Conservancy Areas

Grassed channels, drainageways, and conservancy areas are unconnected storm drainage systems. Storm sewer pipes, curbs and gutters, streets, and parking lots are connected storm drainage systems. *Wherever feasible and practical, we recommend storm water runoff be routed to storm water management facilities and water resource areas by unconnected systems rather than connected systems. We recommend enhanced infiltration practices be applied as a specific component to the storm water treatment train, including infiltration of rooftop runoff and dry swale design incorporated into prairie grass planted conveyance system.* Unconnected systems such as grassed swales, drainageways, and channels can remove substantial amounts of particulates, sediments, and pollutants prior to discharge to the E-Way, wetlands, Nine Springs Creek, and Swan Creek. Directly connected systems directly discharge sediments to those receiving water bodies without any filtration or pretreatment mechanisms. Native prairie grassed channels, swales, and

drainageways should be implemented as a secondary BMP to primary BMPs such as wet-detention and constructed wetland systems. These systems can serve as pretreatment of storm water runoff prior to final treatment by the primary system before it is discharged to the E-Way, wetlands, Nine Springs Creek, and Swan Creek. *Should connected storm water systems be necessary we recommend they discharge to a disconnected system.*

The disadvantages of a disconnected grassed swale, channel, and drainageway as compared to a connected system are increased costs due to long term operation and maintenance. Sediments need to be removed and disposed of on a periodic basis. Mowing, brush work, and continued burning maintenance can be a problem with limited staff and financial resources. However, the advantages of these systems outweighs the disadvantages with respect to increased water quality benefits.

Additional information concerning all of the above-recommended structural best management practices is provided in Appendix G.

C. Recommended Non-structural Best Management Controls

1. Construction Site Erosion Control

Even small areas under construction can have profound effects on water quality since construction site erosion produces such a heavy concentration of sediment load and pollutants that attach to sediment particles.

The City of Fitchburg finds that runoff from land disturbance activities on environmentally sensitive areas and construction sites may carry a significant amount of sediment and pollutants to area waters and public rights-of-way.

The City of Fitchburg has an "Erosion Control and Storm Water Management Ordinance". The purpose of this ordinance is to protect the City's unique natural resources by minimizing the amount of storm water runoff and sediment carried by runoff or discharged from construction sites to perennial waters, E-Way, wetlands, and public rights-of-way. This ordinance applies to land disturbance activities on lands within the boundaries and jurisdiction of the City of Fitchburg.

To control storm water runoff, erosion and sedimentation from construction sites, we recommend that all governing agencies within the

Monona/Yahara Priority Watershed adopt and follow similar provisions, requirements, inspection, and enforcement of the City of Fitchburg Erosion Control and Storm Water Management Ordinance to the maximum extent practical. We recommend that the City update their current Erosion Control and Storm Water Management Ordinance pursuant to the sample model ordinance provided in Appendix F.

A copy of Fitchburg's "Erosion Control and Storm Water Management Ordinance" is provided in Appendix D.

2. Catch Basin Sumps and Cleaning

Recent studies and research by U.S. EPA and SLAMM authors have concluded that storm sewer catch basins designed and constructed with 1.5 foot to 2 foot sumps (holding areas below storm sewer pipe flow lines) provide a tremendous benefit of capturing sediments. The amount of catch basin sediment is very large in comparison with storm water runoff yields. Sediments in catch basins are not very mobile. Therefore, cleaning the sediment from catch basins reduces the potential for very large discharges of sediment during large scouring rains. The sediments found in catch basins are typically the largest particles washed from streets, steep hillsides, and construction sites. The sumps in catch basins can also provide water quality benefits for other pollutants. If catch basin sumps are full of sediment they cannot remove additional sediments and pollutants from the runoff.

Catch basin sediments and particulates can be conveniently removed from sumps to eliminate this potential source of sediments and pollution from being discharged to the E-Way, wetlands, creek, Yahara River, and lakes. *We recommend that all proposed storm sewer catch basins be designed and constructed with sumps and retrofit existing structures where feasible and practical.* They should be cleaned at a minimum two times per year, which will allow the catch basins to capture sediments and particulates for most rains. This cleaning schedule can be expected to reduce the total sediment and pollutant loads in storm water runoff by 10 to 25 percent. They can also reduce loads of other common pollutants such as COD (chemical oxygen demand), total Kjeldahl nitrogen, total phosphorus, and zinc by 5 to 10 percent.

We recommend that storm sewer catch basins and structures be cleaned at a minimum of twice a year. These structures should be cleaned in late spring or early summer and in the fall of the year. Storm sewer catch basins will need to be monitored on a regular basis to adjust the frequency needed for cleaning. Some areas may require

more frequent cleaning and other areas may require less frequent cleaning. *We recommend that a schedule and agreement between the City of Fitchburg, City of Madison, Town of Madison, State, and County be devised to determine which governing agency has jurisdiction in particular areas.* Typically all County Trunk Highway drainage structures should be addressed by the County, Town roads by the Township, City streets by the City, and State and U.S. Highways by the Wisconsin DOT.

3. Street Sweeping

Past research and studies show that street sweeping has limited success as a BMP on existing urban land uses if automobiles are not moved away from the curb during sweeping operations. However, street sweeping can be used in conjunction with other BMPs to control sediments and pollutants in storm water runoff.

We recommend that street sweeping or increased street sweeping be implemented within the Nine Springs Neighborhood and surrounding watershed areas, including City and Town of Madison, as development increases to provide some benefits beyond cleaning sediments and pollutants from streets. Street sweeping is very visible and can be used as an information and educational tool to promote public awareness of sediment transport and storm water pollution.

Street dirt size and loadings, street texture, moisture, parked car conditions, and equipment operating conditions significantly affect street cleaning performance. Street cleaning can be more effective in industrial and commercial areas, especially if paved parking and storage areas are effectively cleaned. Frequent street sweeping with the proper equipment and removal of parked vehicles in these areas could reduce sediments and pollutants by approximately 70 percent. However, more common industrial and commercial street sweeping and cleaning programs are approximately 10 percent effective because of limited or no parking lot sweeping.

Street sweeping and cleaning within industrial and commercial areas should be done, at a minimum, on a monthly basis by the respective property owners beginning in the early spring and ending in the late fall of the year.

Street sweeping and cleaning within City streets, and heavily traveled Town roads, County Trunk Highways, and STH should be addressed at a minimum on a monthly basis in early spring and late fall. City of Fitchburg should continue their current street sweeping policies and increase the frequency schedule where feasible and practical.

Cooperative agreements may be worked out between these governing agencies to delegate areas of responsibility with reimbursement from each agency to the other.

4. Agriculture Land Management Practices

We recommend that the farm community and Dane County Soil Conservation Service continue with their crop rotation program, residue management program, barnyard runoff program, and proposed site specific land management practices to control soil erosion, sedimentation, fecal coliform, and phosphorus discharges from agricultural lands. Alternative row crops with hay, oats, and alfalfa reduce the amount of soil erosion and runoff. Land management practices will preserve the fertility and productivity of soils and improve the water quality of the E-Way, wetlands, creeks, Yahara River, and lakes.

We recommend that agriculture land management practices continue to be implemented to the maximum extent practical. Farming hay, oats, and alfalfa as a buffer area near sensitive water resources where soil can easily erode and run off into adjacent water bodies is recommended rather than row crops. A prairie grassed buffer strip adjacent and along sensitive areas will help filter out phosphorus and capture sediments prior to discharge to the E-Way, wetlands, creeks, Yahara River, and lakes.

5. Wellhead Protection

Improper management of contamination sources results in groundwater contamination of public water supply systems. One approach toward preventing such contamination is to protect the areas that recharge precipitation and surface water to the aquifer near the wells.

Human activities, facilities, and land uses can ultimately lead to groundwater quality and recharge problems. Accordingly, land use management, including regulation, may be used to protect the quality of drinking water supplies. The basic idea of a well protection program is to restrict potentially polluting activities near proposed wells and well field and within recharge or "catchment" areas of aquifers supplying water to these wells. Generally, activities are more restricted close to the well and less so farther away.

a. What is Wellhead Protection?

Wellhead protection is, by definition, protection of the area surrounding a well. A “wellhead protection area” is the surface and subsurface area surrounding a well or well field that supplies a public water system through which contaminants are likely to pass and eventually reach the water well or well field. Wellhead Protection Area boundaries are determined based on factors such as well pumping rates, time of travel of ground water flowing to the well, aquifer boundaries, and degree of confinement. All of these hydrogeologic characteristics have a direct effect on the likelihood and extent of contamination.

Because of the harmful effects of polluted groundwater on human health and economic activities, local governments are becoming more concerned about protecting the quality of their groundwater. Many local officials have recognized the need for a systematic program of groundwater quality management outlining specific strategies and action for maintaining and improving the quality of groundwater.

One basic element of such a program is identifying goals and objectives. Additionally, it is important to identify what land use activities have the potential to cause pollution and to determine whether these practices are being carried out in pollution-sensitive areas. This requires an evaluation of how the environment can affect or be affected by pollution. Soils and geologic materials in some areas can attenuate certain pollutants before they reach the groundwater; in other areas, pollutants can readily enter groundwater.

The next step involves an inventory and analysis of the existing condition of the groundwater. Knowledge of current water quality conditions is important for determining any future quality changes, identifying areas where groundwater quality is impaired, and for relating the extent of impairment to different land uses or sources of pollution.

Once background information is collected and analyzed, the type of management techniques needed to address specific problems can be identified. Options range from a comprehensive program to focusing on a particular source of pollution or specific areas where several potential sources of pollution are a problem.

Preliminary groundwater contribution zones for the City of Fitchburg's existing and proposed high capacity wells have recently been determined by the Dane County Regional Planning Commission. These zones of contribution can form the basis for identification of suitable wellhead protection zones for each existing and proposed well.

An element of a Wellhead Protection Plan may be a Wellhead Protection Ordinance that regulates land use in those areas that provide the groundwater for the municipal water supply wells. The regulations of this ordinance may include zoning regulations that are applied as an overlay district to the underlying zoning. For example, if a certain land use is allowed in the underlying district, it may be prohibited in the Wellhead Protection Ordinance overlay district or may be allowed as a conditional use with certain regulations applied. In many ordinances, land uses are prohibited which have a history of contaminating groundwater (e.g. underground storage tanks).

Some unique aspects of a Wellhead Protection Ordinance may include:

- Restricting application of fertilizers on residential lots by enacting a strong chemical, fertilizer, herbicide and pesticide ordinance, and encourage local stores to provide and residents to use no-phosphorus fertilizers.
- Requiring farm plans for agricultural operations to minimize impacts of pesticides and fertilizer on groundwater
- Basing applications of sewage sludge and animal waste on the nutrient requirements of the crops being grown
- Requiring secondary containment for certain petroleum product and pesticide or fertilizer tanks
- Regulating storm water drainage from commercial and industrial properties.

Examples of permitted uses in an identified Wellhead Protection Area may include:

- Parks, playgrounds
- Wildlife areas
- Non-motorized trails, such as biking, skiing, nature, and fitness trails
- Sewered residential uses

Typical prohibited uses or uses with restrictions may include:

- Underground storage tanks
- On-site private sewage systems
- Septage and/or sludge spreading
- Animal waste land spreading and facilities
- Animal confinement facilities
- Gas stations
- Landfills
- Salt storage
- Bus and truck terminals

Wellhead Protection Ordinances also often address existing facilities by requiring that they file contingency plans for hazardous events, that any equipment replacement or retrofitting is in compliance with current laws, that the uses provide additional environmental or safety structures/monitoring as deemed necessary by the City that may include, but are not limited to, storm water runoff management and monitoring. *A copy of a typical Wellhead Protection Ordinance is provided in Appendix E.*

6. Comprehensive Storm Water Management Ordinance

A comprehensive storm water management ordinance that is well-prepared provides the City of Fitchburg the legal framework to require suitable storm water best management practices provided in this plan to diminish the threats to public health, safety, welfare, and the natural and aquatic environment due to runoff of storm water from agricultural and land development activity. Specific purposes are to:

- Further the maintenance of safe and healthful conditions;
- Prevent and control the adverse effects of storm water; prevent and control soil erosion; prevent and control water pollution; protect spawning grounds, fish, waterfowl, and aquatic life;
- Control exceedance of the safe capacity of existing drainage facilities and receiving water bodies; prevent undue channel erosion; control increases in scouring and transportation of particulate matter; prevent conditions that endanger downstream property;
- Control building sites, placement of structures, and land uses, and promote sound economic growth.

A sample storm water management ordinance is provided in Appendix F. A companion document with the ordinance should contain the Nine Springs Neighborhood Plan recommended standards and specifications for BMP installation. *We recommend that the City of Fitchburg consider revising their current storm water management ordinance similar to the sample document and codify existing practices that are beyond the current ordinance.*

7. Public Education and Information Program

Changing urban storm water management will require investments in information and education as well as in research, engineering and construction. A carefully conceived and administered information and education program is essential for several reasons.

First, few people are aware of the problems caused by flooding, sedimentation and pollutants in storm water runoff or the common sources of flooding, sedimentation and pollutants. Before the public, developers, and farmers will support changes in flood control, pollutant reduction and storm water management controls, they must understand the need for these changes.

Several storm water structural treatment and flood control methods such as detention, infiltration, and biofiltration are unfamiliar. Therefore, they are not widely accepted by many farmers, urban residents, local governmental officials, and developers.

New technology, research, engineering design, construction, and maintenance techniques for storm water treatment and flood control devices are evolving as these devices gain wider use. Therefore, local governmental agencies and construction industry staff need to regularly share experiences and learn about the latest developments in the field.

Urban developments and agricultural practices originally desired storm water systems for drainage and water quantity, not for sedimentation and pollution control. Public expectation and engineering practices must change to expand storm water management and include wet detention, infiltration, sedimentation, and pollution prevention. Since sedimentation and pollutant sources are so wide-spread, the farmers, developers, and public need to cooperate in carrying out pollution prevention, which is the most effective control.

The public education program should include individual and societal changes. Changes in human behavior seldom occur overnight.

From an individual perspective, there are three basic steps to change: awareness, acceptance, and implementation. A person must first recognize a problem exists and understand what causes that problem, then the person must overcome any resistance and accept the solutions. The person is ready to learn how to carry out the solution only after completing these steps.

Societal change is more than an individual process, it is also a group process. People adopt new practices at different rates. Some people are more willing to take the lead and experiment. Others will wait until the "bugs are worked out" and adopt the practice only after they have proof that it works. Some will resist until they are forced to change. *Thus societal change also has three basic steps: innovation by a few, voluntary adoption by the leaders, and mandatory compliance by the rest.*

We recommend that an information and education program be implemented to adapt to these different stages of individual and societal change. First you must build public awareness of the impacts of urban and rural storm water runoff with an understanding of the sources of flooding, sediment and pollutants. Then you need to overcome the developers', farmers', and public's resistance to flood control, sedimentation, pollution prevention, and control practices by encouraging those who are willing to try them. Information from the experience of these innovators must be used to improve the practices. The successes of these innovators must be shared with others to encourage the leaders to adopt the new storm water management techniques. Support required for widespread implementation of storm water controls is built once a solid foundation of awareness, acceptance, voluntary adoption, and feedback is accomplished.

Public education and information programs can use newsletters, news releases, public information meetings, and field trips. The overwhelming temptation in developing an information and education program is to use a "shotgun" approach and plan to do a little bit of everything with the hope that something will work. The reality is that when faced with the day-to-day demands to provide good service and hold down the tax levy, most communities invest very little time and effort in information and education. We recommend the best approach is to lie somewhere between these two extremes. The program strategies should achieve specific objectives by educating key audiences whose actions or support are needed to carry out change.

We recommend the first step in developing an information and education strategy for the Nine Springs Neighborhood is to utilize this

plan and prioritize what needs to be done first. The City should determine which audiences need to receive what information to achieve a certain change and commence with implementation. These decisions can be summarized in a list of long-term goals supplemented by a list of objectives for each year. After completing this, select appropriate activities to accomplish each objective.

Funding Options

XI. FUNDING OPTIONS

Listed below are descriptions of funding options which may be available to the City of Fitchburg and adjacent watershed governments.

A. State/Federal Grants and Loans

Historically, local governments have experienced infrastructure funding support from state and federal government agencies in the form of direct grants in aid, interagency loans, etc. It is important to assess likely trends regarding federal/state assistance for storm water management financing. Future trends indicate that grants could be replaced by loans in the form of revolving funds.

The State of Wisconsin has been reviewing the need to include storm water management and water quality based projects under the Clean Water Fund low interest loan program. This program has been used to finance projects such as wastewater treatment plant projects for years. Direct loans through local financial institutions are another loan funding alternative.

The Nine Springs Watershed's storm water runoff discharges to the Yahara River and Lake Waubesa. This watershed is unique because it is within the Monona/Yahara Priority Watershed and discharges to a lake which potentially qualifies for both federal and state funding assistance. Grants from State Department of Commerce Community Development Block Grant Program, Tax Incremental Financing Program, DNR EPA Section 319 Non-Point Source (Priority Watershed) Program, DNR Clean Water Fund, DNR Stewardship Program, and DNR Water Quality Planning Grant (604B) are some of the available grant funding sources that will need to be investigated.

B. Development Charges

Wisconsin Statute 66.55 regulating impact fees took effect in April 1994. All municipalities must be in compliance with this statute if they intend to collect impact fees. Impact fees are contributions paid by public facility users who create a need for increased capacity in the public facility.

These charges (impact fees, buy-in fees) are designed to provide a mechanism by which owners of properties which will be developed in the future share in the current cost of constructing storm water management improvements. Storm water management improvements are characteristically designed to last twenty years or more. The requirement that owners of future developed properties enjoy the benefits of the improvements at no incremental cost is often considered inequitable. The use of system development charges can provide important revenue source flexibility. Questions regarding who should pay for required upsizing of

storm water conveyance and detention structures due to new development or how can historical ratepayers recover their costs in oversizing facilities that enable future growth are the types of equity issues that system development charges can be designed to accommodate.

C. Fee-In-Lieu Of On-Site Detention/Retention

In-lieu of fees can either be a regulatory requirement of a development option that offers developers the opportunity to construct on-site detention/retention facilities in accordance with the established design criteria or pay a fee into a fund dedicated to the construction of an off-site detention regional facility serving multiple properties. The approach encourages the siting and construction of more regional versus on-site facilities. Fee-In-Lieu of programs are effective in guiding development patterns within a watershed and as a tool to encourage comprehensive storm water planning.

Fee-in-lieu of procedures have a downside. Since construction timing and cash flow are critical, the usual fee for a single property or development may not be large enough to fund the construction of an entire regional facility. Therefore, either multiple developments must occur simultaneously in a given area to generate enough revenue to fund the construction of a regional facility, or, the project must be funded up-front from other sources. Service charges and borrowing from other funds can provide the necessary initial resources for construction. These funds can then be repaid by in-lieu of fees.

D. Special Assessments

For over a century, Wisconsin municipalities have used special assessments as a method to finance local improvement projects. Special assessments are flexible and they can be used to pay for public improvements such as storm water management facilities. In addition, because only those properties which specially benefit from the improvement bear the improvement cost, the general property tax is not further burdened. Therefore, special assessments are useful financial tools for municipalities. Their usefulness has increased as demand continues to grow for each municipal tax dollar.

The procedures for levying special assessments is prescribed by Wisconsin law. Special assessments can be levied against property specially benefitted by a public improvement or work. Municipalities specially assess under either of two optional powers granted to them by the Special Assessment Statute, Sec. 66.60. The police power allows the local legislative body to enact ordinances and take action ". . . for the health, safety, and welfare of the public." The taxing authority is the general power of any government to levy taxes on its citizens to pay for improvements and services provided. The difference between specially assessing under either

power lies in the criteria necessary to establish the amount to be assessed and the procedures to be followed in the special assessment process. Accordingly, under the police power, the governing body must determine the actual existence of benefits, while under the taxing power it must calculate the value of the benefits conferred.

The use of special assessments to fund storm water management projects often encounters obstacles to its implementation, not the least of which is the difficulty in quantifying the benefit to individual properties. Typically, the benefit is determined through frontage along the improvements or areas within the improvements. In storm water management, owners upstream or hillside properties that can be major runoff and water quality contributors may not be specific recipients of project/maintenance benefits and, therefore, not supportive of storm water control efforts.

E. Plan Review and Inspection Fees

These are intended to recoup the expense of examining development plans to ensure compliance with ordinances and storm water management/master plans, and to insure that construction standards and regulations are met in the field. These fees are not designed to be primary revenue generators. Charges are usually limited to administrative, engineering review, legal, and field inspection costs incurred by the governing agency. Plan review and inspection fees are designed to allocate direct costs back to those receiving the service.

F. Storm Water Service Charges

Another method of generating a dedicated source of revenue is the service charge. Many storm water programs support capital improvements through a variety of aforementioned funding sources while maintenance/operations are funded through a service charge.

The rationale underpinning the service charge method is that those who contribute to storm water problems should logically contribute to the cost of providing solutions to those problems. There are numerous combinations and variations of rate structures available, three are described below:

1. Amount of Impervious Surface

Rates are set in direct proportion to the impervious surface of a lot, parcel of land, or other accepted land measurement. The determination of impervious surface may be by estimating actual measurement, or accepted percentage of impervious surface based on type of land use.

2. Density of Development

With this approach, rates are determined by a runoff coefficient based on land use and type of improvements.

3. Flat Fee

This is a uniform fee for each property within determined classes. Of the three approaches, this offers the most administrative simplicity.

G. Taxation

Local governments historically funded storm water management services with Ad Valorem Property Tax Revenue.

The rationale for local government involvement (taxation) is the public benefits in managing runoff. The rationale for the financing mechanism (taxes) is either (1) higher valued properties benefit more, or (2) owners of higher valued properties can pay more for a public good (the benefits available to everyone that cannot be quantified). Unfortunately, this means storm water expenditures must compete with other local government services and, consequently, funding is highly variable. With this disparity, local governing officials often give low priority to maintenance of drainage infrastructure.

With property taxes as a financing mechanism, equity of funding is a concern. Residential and commercial property owners are better served under a charge or utility system (see Utility Structure Overview) and industrial property owners, in general, are better served under a property tax system. Commercial property owners are better off with the user charge system. Owners of agricultural land and exempt parcels are better off under the tax system.

If property values reflected benefits of storm water management, the property tax system could be more equitable.

H. Bonding

Long term borrowing can effectively finance storm water projects within a municipality. A municipality can use bonding authority to issue long term bonds for storm water systems. Issuing bonds is less expensive than financing a project with a bank loan because it eliminates the "middle person" when borrowing money.

A long-term municipal bond is characteristically exempt from federal taxation. The federal government does not tax the interest on local securities through income taxation. State and Federal Governments may tax their own securities, although most do not exercise this right.

When a municipality wants to issue a bond, it must go through a rating process to learn how secure the municipality is from defaulting on this security. Receiving the highest rating makes it easier for a municipality to sell bonds. If a lower rating is received, in some cases the municipality must find an underwriter to help secure financing.

There are limits on the amount a municipality can borrow in Wisconsin. The indebtedness of a municipality cannot exceed five percent of the taxable property value within its boundaries. This limit ensures some proper fiscal management when borrowing. Certain types of bonding must also go through a referendum, which gives the public a chance to vote on issuing bonds.

A Wisconsin municipal bond can be issued for 20 to 50 years. For additional information on long-term bonding and legal requirements, refer to Wisconsin State Statutes Chapter 66: Municipal Law, and Chapter 67: Municipal Borrowing.

I. Storm Water Utility

Over the past few years, the concept of creating a storm water utility has become popular. The utility approach redefines how people think about runoff and storm water management. A basic premise in the utility approach is that runoff is a man-made problem and property owners are responsible. This approach designates property owners as storm water generators with a government authority controlling these discharges. To finance government activities, property owners pay user charges or fees proportionate to their discharges. This utility approach uses the "polluter pays" principal. The American Public Works Association (APWA) concludes:

"The user charge and utility concept are the most dependable and equitable approaches available to local governments for financing storm water management."

Care must be taken when forming utilities. Listed below are steps to consider:

- Document the need for Storm Water Utility Program
- Educate Administrative Staff
- Establish a Steering Committee
- Develop a Public Participation Program
- Develop a Comprehensive Implementation Plan
- Calculate Current Storm Water Program Costs
- Estimate the Storm Water Revenue Needs
- Prioritize Needs and Projects
- Establish a Preliminary Budget
- Create a Rate Structure
- Refine Budget and User Charges
- Prepare a Storm Water Utility and User Charge Ordinance
- Develop a Billing System

Funding mechanisms vary greatly among storm water utilities. In many instances, fees are based on a formula related to impervious surface area as a measure of the amount of runoff that flows from any individual site.

Like any other utility, the rate structure must be established on the basis of need. *In some instances, a fee structure for a new storm water utility has been introduced in two phases: a small assessment to fund planning and permit processing start-up and a larger assessment to pay for new capital facilities. In other locales, the decision may be made to fund a project(s) by issuing bonds in order to have the construction money up front, or by setting up a system in which improvements are made by the utility as the funds became available.*

In many cases, fees are based on a standard often called an "Equivalent Residential Unit" (ERU). For instance, each single-family residence can be estimated to cover an approximate square-foot of impervious surface (i.e. 2500 sq. ft = 1 ERU): A commercial or industrial structure actually covering 5,000 sq. ft. would be equal to 2 ERUs ($5000 \div 2500$) and be assessed a fee two times the single family rate. The utility concept, and especially a charge based on impervious surface or runoff is a fair way to fund storm water management improvements because fees are based on the actual use of a public facility rather than on property values. The latter, property values or an ad valorem millage, may be viewed as inequitable since it may be difficult to establish a nexus between the fee (exaction) and the benefits derived. *A storm water utility ensures a dependable, dedicated source of revenue earmarked for storm water management that can be restricted from use for other governmental purposes. A dedicated revenue source also enables governmental entities to issue*

revenue bonds to help finance the cost of major capital projects. In addition to acting as a financing mechanism, the utility acts as an organizational unit responsible for managing storm water concerns, allowing a planned, systematic approach to both water quality and quantity management programs.

Implementation and Summary Recommendations

XII. IMPLEMENTATION AND SUMMARY RECOMMENDATIONS

A. Implementation Strategy

1. Establish Storm Water Utility District

As discussed throughout the plan, storm water can cause a multitude of problems in agricultural and urban settings, from flooding to degrading the water quality of the E-Way, wetlands, creeks, rivers, and lakes that eventually receive it. The City of Fitchburg and municipalities within the same watershed and basins share similar storm water problems, linked by hydrologic, hydraulic and pollutant loading characteristics. As localities begin to deal with the effects of storm water, they often find they can realize economics of scale by working together. Since storm water quality and quantity is obviously not a problem confined to jurisdictional boundaries, government units within a watershed basin should carefully consider joining together under a newly established authority and applying a systematic and basin-wide approach to solving storm water quality/quantity problems. One approach to dealing with storm water on a watershed basis many communities are looking to is the establishment of a storm water utility. A utility approach has the principal advantage of shifting the cost of construction directly to developers, farmers and property owners, who are the direct beneficiaries, without incurring further public debt. Though this often may be the most desirable, it is not always possible to have a single developer construct a storm water management facility that may very well serve areas beyond the subject development site. In those instances, it may be more practical that the storm water utility district finance, design, and construct the regional watershed or sub-basin facilities before most urban development occurs, with recapture or reimbursement by developers, farmers and property owners over a 5 to 20 year development period. The revenue raising ability of the storm water utility may be more appropriate and able to fund larger scale storm water facility construction and obtain greater benefits.

It is recommended that the City of Fitchburg and adjacent political entities all or partially located in the watershed as defined by this plan form storm water utility districts to not only address existing water quality and quantity problems but to also implement the following recommendation in order to avoid further problems or exacerbate existing storm water problems.

2. Implement an Ecological System Restoration and Management Program

It is important to recognize that existing E-Way, creeks, woodlands, streams, lakes, and wetlands have been adversely affected by over a century of agricultural drainage and urban development activities.

The City of Fitchburg should work with Dane County and City of Madison to implement an ecological restoration and management plan for enhancing or restoring the degraded ecosystems, ideally on a watershed basis as recommended in Section V.

Where degraded creeks, woodlands, and wetlands exist on agricultural and development sites, developers and farmers may be authorized and encouraged to design restoration measures into their site and farming plans. Restoration might entail restoring vegetation, habitat structure, biological and biogeochemical functions; maintenance, prescribed burning, ecological monitoring, annual reporting, stream de-channelization, replanting stream banks with native vegetation, or creating open water areas in and around sedimented wetlands. These types of restoration measures also benefit the developer and farmer by enhancing the appearance of the site and enhancing property values.

3. Implement Effective Ecological Protection Regulations

The degree to which the City of Fitchburg will choose to regulate sensitive natural resources will generally depend on the quality of the resource and perceived agricultural and development-related concerns. *The City of Fitchburg should establish stringent minimum setback requirements between construction activities and all significant creeks, E-Way, drainageways, springs, groundwater recharge areas, and wetlands. It is recommended that the City establish 75 foot wide corridors along stream, drainage channels and wetlands, such corridors being composed of a 25 foot wide minimum strip of native plant vegetation. Greater width native vegetation corridors should be encouraged. Twenty-five foot wide minimum buffer strips should also be established adjacent to the high water mark of all storm water ponds.*

4. Encourage Reduced Setbacks

Reducing front building setbacks within proposed urban curb and gutter street section areas, thereby reducing the lengths of driveways and entry walks, *and providing minor reductions to impervious areas and corresponding storm water runoff volumes*. This is most readily accomplished along low-traffic streets where traffic noise is not a problem and within low residential density and clustered development areas.

5. Re-evaluate Street Width Requirements

Existing City street width requirements are commonly based on access criteria for emergency vehicles, parking and snow plowing. From an environmental perspective, narrower streets *means reduced construction and maintenance costs, less storm water runoff and reduced flooding and water quality impacts*. Street widths may be reduced by eliminating on-street parking or by reducing the width of moving lanes where practical and feasible.

6. Encourage Natural Drainage Designs

Natural drainage utilizing swales and prairie grass vegetated filter strips has strong environmental advantages over traditional drainage approaches which utilize storm sewers and curb and gutter streets. *These include reduced runoff volumes, reduced storm water pollutant loads, and greater recharge of groundwater*. Natural drainage also can be less expensive than storm sewers. Swales are suitable for many types of development, but are probably most practical on large lot residential sites (e.g., ½ to 1 acre or larger), some multi-family developments, campus type office/industrial sites, and highways where the number of driveway crossings is at a minimum. Swales are most easily implemented within low residential density and clustered development areas on rolling to gently rolling topography. Despite their many advantages, swales are discouraged by many municipal subdivision codes. Commonly cited concerns include prolonged ponding of water, loss of pavement edge, maintenance requirements, and freezing and overflow during winter conditions. On appropriate sites these concerns can be minimized or eliminated with proper design and installation, land use density regulations, and effective public education.

7. Encourage Native Vegetation for Landscaping

Landscaping with native plants is growing in popularity, and has important advantages over traditional approaches. Native prairie grasses, wild flowers, and shrubs require less maintenance—fewer mowings, less fertilizer and pesticides, and less irrigation—than turf grass. *As a consequence, native vegetation is less expensive to maintain, more energy efficient, and contributes fewer pollutants in runoff water.* Native prairie grasses are deeper rooted encouraging maximum infiltration rates and limiting the need for pesticides and lawn care fertilizers, thereby providing superior stabilization on steep slopes and better protection of sensitive areas such as creek banks, E-Way, wetlands, and lake shores. Native vegetation also provides wildlife habitat and visual variety.

8. Reduce Parking Requirements

Off-street parking requirements are often an integral part of many zoning ordinances. Modifications in the number of spaces and the type of material required for parking lot construction may be environmentally beneficial: replacing or augmenting minimum parking space requirements with maximum limits may encourage people to use alternative modes of travel, and *minimizing surface runoff by incorporating greenspaces into parking lot designs* or by encouraging parking lot construction with porous materials, where appropriate. Adopting provisions for land banking is an approach that permits the review of parking requirements for commercial and office development and altering the number of parking spaces required. The City may also modify parking requirements to promote shared parking facilities among multiple uses.

9. Encourage Cluster Developments

One of the best ways to minimize the disturbance of sensitive areas and natural drainage features while allowing for reasonable economic use of the land is to utilize cluster developments. Cluster development maintains the gross density of the site (i.e., the same number of lots) but clusters the development onto the buildable portion of the site. Cluster designs *allow for natural drainage, thereby absorbing rainwater and reducing flooding impacts.* Cluster developments can save on the cost of site disturbance, site clearance, street pavement, and storm sewers.

10. Wastewater Service Areas

Future service should be phased-in in an orderly fashion to promote contiguous development from a downstream to upstream fashion,

servicing isolated upland pocket developments should be discouraged. Certain areas should not be served by sewers because of development, limitations or alternative service options.

Recommended non-service areas include wetlands, floodplains, state and county designated natural areas, critical groundwater recharge and spring areas, agricultural protection areas, and public open space.

11. Provide Effective Wet Storm Water Detention

Accepted storm water detention standards have evolved significantly. Recommended detention storage volumes have increased based on new information on statistical rainfall amounts and evaluations of detention performance. Detention release rates should be based on the natural carrying capacity of downstream channels and floodplains. Release rates also should be controlled for smaller storms such as the 2-year event to reduce the occurrence of downstream channel erosion. *Detention should be designed to reduce water quantity discharges and remove storm water pollutants through improved settling, filtering, and biological uptake.* These functions are achieved in basins designed like natural wetlands and/or wet sedimentation/detention ponds.

12. Construct Storm Sewers Only Where Necessary

This is the least preferred element of the runoff reduction hierarchy because storm sewers do not accomplish runoff infiltration, groundwater recharge, pollutant filtering, or flow attenuation; their only purpose is to convey runoff. While storm sewers are necessary in many developments, there is an over-reliance on them in many instances. Storm sewers should be constructed in areas where other natural drainage designs are not feasible and practical.

13. Educate Residents About Natural Drainage Approaches

The storm water management plan approach recommended will result in visible water flowing and temporary ponding on the ground surface in designed swales, ditches and detention facilities. While this approach resembles the natural system, some residents and property owners may be disturbed because water does not “magically” disappear immediately after every rain. Public education will be helpful in conveying the rationale for this approach and in keeping inappropriate activities (e.g., fences, trees, shrubs, and structures) out of drainage easements.

14. Identify Appropriate Floodplain Uses and Zoning

Effective land planning for storm water management must reflect a wise balance between Nine Springs Neighborhood development needs and the protection of natural functions. This may be accomplished by zoning which identifies appropriate uses. Uses should not impair natural drainage functions and should not increase the neighborhood's liability for flood damages. Identified appropriate uses should include native prairie grass trail and drainage system, passive recreation, lawns, and water dependent activities. Prohibited uses should include parking lots, buildings, most roadways (except where necessary for crossing a creek or drainageway). Sensitive areas adjacent to E-Way, creeks, drainageways, and wetlands may be provided additional protection by requiring buffers of native vegetation.

15. Implement Open Space Opportunities

Targeting identified local open space acquisitions to E-Ways, creeks, drainageways, wetlands and environmentally sensitive areas is an effective and popular option. These acquisitions should be coordinated with Nine Springs Neighborhood Plan, regional open space and greenway recommendations, this storm water plan, and with the plans of county and state storm water management agencies. Lands can be acquired by State Stewardship Program, outright purchase or by mandated park donations from developers. Because of the regulatory constraints on developing these areas, the cost of land may be much lower than surrounding property. Another effective mechanism for protecting open space is the creation of conservation easements.

16. Implement Comprehensive Storm Water Management Ordinance

A storm water ordinance provides the legal framework to require suitable management practices to reduce flooding and degradation to natural and water resources. An ordinance provides performance and construction guidelines and promotes consistency with a BMP.

Storm water ordinance elements to be considered shall include:

- Findings of Fact/Purpose and Objectives
- Authority/Jurisdiction
- Definitions
- Applicability
- Plan Review

- Enforcement
- Performance Standards
- Off-Site Regional Management Facility
- On-Site Individual Management Facility
- Maintenance
- Performance Bond
- Appeals
- Variance Procedure

A sample storm water management ordinance is provided in Appendix F. A companion document with the ordinance should contain this plan's recommended standards and specifications for BMP installation.

17. Wellhead Protection

Protecting the groundwater supply before it becomes contaminated, instead of waiting until contamination occurs, is both smart and cost effective.

Protecting groundwater supply wells from contamination can be accomplished in five basic steps:

1. forming a planning team
2. defining the area to be protected
3. identifying and locating potential contaminants
4. Managing the protection area
5. planning for the future.

5-Step Groundwater Protection Plan

- Step 1: Form Planning Team
Select a representative group of community members for planning team
- Step 2: Defining Area to be Protected
Identify the area needing protection using the zones of contribution, as defined by the Dane County Regional Planning Commission, and work with DCRPC to better define these estimates. Groundwater passes through areas surrounding the well site that could affect the quality of the water.

- Step 3: Identify and Locate Potential Contaminants
Pollutants released within the defined area have the potential of reaching the well and causing contamination. Sources of groundwater contamination could include: agricultural, commercial, and residential sources.
- Step 4: Manage the Protection Area
It is necessary to identify the risks present and to develop a plan to manage the protection area. Two broad categories of management tools available are regulatory and non-regulatory controls. Regulatory controls include land use plans, zoning ordinances, and subdivision regulations for example while non-regulatory controls may include educating the community about the well head protection program with fliers or pamphlets or acquiring land within the protection area.
- Step 5: Planning for the Future
Develop a contingency plan with procedures for responding to a crisis and ideas for alternative water supplies.

B. Cost of Implementation

The following are preliminary opinions of probable construction costs for recommended flood control and water quality control facilities. These cost estimates are based on field observations, investigations, preliminary analyses, and existing topographic maps. Probable costs will need to be refined following field surveys, soil borings, hydrogeological and geotechnical investigations, and detailed engineering and design.

The following are our recommended priority of construction, improvements and summary of costs over a 15-year period to address the problems and concerns based on proposed development staging plan and probable severity as analyzed within the watershed.

1. Immediate Improvements - 1 to 5 Years $\pm$
 - a. Construct Wet Detention/Sedimentation Basin F1 (includes land cost $5\pm$ AC) \$140,000
 - b. Construct Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "F" (includes land cost $20\pm$ AC) \$270,000

c.	Construct Wet Detention/Sedimentation Basin G1 (includes land cost 1± AC)	\$ 27,000
d.	Construct Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "G" (includes land cost 2.5± AC)	\$ 33,000
e.	Construct Wet Detention/Sedimentation Basin H1 (includes land cost 6.5± AC)	\$175,000
f.	Construct Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "H" (includes land cost 15± AC)	\$200,000
g.	Ecological Restoration and Management	\$ 50,000
h.	Miscellaneous Streambank and Channel Erosion Control Measures	<u>\$ 20,000</u>
	Subtotal:	\$915,000

2. Intermediate Improvements - 5 to 10 Years ±

a.	Construct Wet Detention/Sedimentation Basin D1 (includes land cost 3.5± AC)	\$100,000
b.	Construct Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "D" (includes land cost 20± AC)	\$270,000
c.	Construct Wet Detention/Sedimentation Basin D2 (includes land cost 3± AC)	\$ 80,000
d.	Construct Wet Detention/Sedimentation Basin E1 (includes land cost 7± AC)	\$190,000
e.	Construct Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "E" (includes land cost 20± AC)	\$270,000
f.	Ecological Restoration and Management	\$ 50,000
g.	Miscellaneous Streambank and Channel Erosion Control Measures	<u>\$ 20,000</u>
	Subtotal:	\$980,000

3. Ultimate Future Improvements - 10 to 15 Years ±

a.	Construct Wet Detention/Sedimentation Basin A1 (includes land cost 8± AC)	\$220,000
b.	Construct Wet Detention/Sedimentation Basin B1 (includes land cost 4± AC)	\$100,000

c.	Construction Conservancy/Park/Prairie Grass Vegetation Water Quality Buffer Areas Within Subarea "A" (includes land cost 8± AC)	\$108,000
d.	Construct Wet Detention/Sedimentation Basin A2 (includes land cost 8± AC)	\$220,000
e.	Ecological Restoration and Management	\$ 30,000
f.	Miscellaneous Streambank and Channel Erosion Control Measures	<u>\$ 20,000</u>

Subtotal: \$698,000

TOTAL in 1998 Dollars: \$2,593,000

These priority based storm water management water quantity and quality improvements are intended to be planned and phased over a number of years to coincide with funding availability and private development of undeveloped land. These costs only include typical BMP construction costs within the Nine Springs Neighborhood Watershed Area shown on Map Exhibit No. 4 in Appendix B. These costs do not include typical long-term operation and maintenance costs.

The total Nine Springs Neighborhood Watershed Area is approximately 1705± acres. This results in a cost of approximately \$1,520.00 per acre of gross land area. The gross land area includes the E-Way, parks, and public rights-of-way, etc. Delineated and mapped wetland areas are not included in the gross acreage.

C. Implementation Benefits

Natural and water resources must be more wisely managed, protected, and developed. Improved measures to control flooding, erosion, sedimentation, and pollutants must be put into practice. For much, if not all, development and farming within the Nine Springs Neighborhood, there are ways to farm and redevelop the land, improve site drainage, enhance property value, reduce public and private expense, and decrease impact on natural ecologically sensitive areas.

Through improved site and land design, local storm water runoff management, ecological restoration and management supported by both ordinances and voluntary cooperation at all levels, improved storm water quality and quantity are achievable. If the objectives can be achieved, the City of Fitchburg Nine Springs Neighborhood and surrounding areas will enjoy new improved benefits and lowered costs through the years to come.

1. **Minimized Erosion and Sedimentation**

Proper native vegetation ditch design, spoil handling, no-till farming, ditch slope grassing and maintenance, curved swale and berm design, wet detention pond development, and retaining large areas of native landscaping and other high-infiltration surfaces can all go far to improve both on-site and off-site drainage. With improvement, farming, houses and other structures set upon the higher ground of graded earth will be better protected from storm water. At the same time, there will be less erosion and sedimentation of E-Way, creeks, wetlands, and drainageways and less flooding from filled drainageways.

2. **Improved Water Quality**

By farming, construction of developments, and storm water management systems at satisfactory heights above the groundwater, we will decrease chances that storm water runoff pollutants will reach and contaminate water supplies and recreational water bodies. The slowing down of rapid storm water runoff and pretreatment of storm water runoff can also improve water quality in creeks, E-Way, wetlands, rivers and lakes by reducing erosion, pollution, and siltation.

3. **Protected Ecosystems**

By implementation of an ecological system restoration and management plan, and limiting erosion and sediment loads in drainageways, the problems of siltation and filling in of wetlands and waterways, can be reduced. Proper drainage control can thus result in improved environmental quality and help protect and improve fragile ecosystems and the valuable fisheries and wildlife species they support.

4. **Minimized Public and Private Costs**

By employing techniques as outlined, farmers, homeowners and other property owners can limit the expense they incur from the costs associated with clean-up, repair, ecological degradation, and replacement of flood damaged features. Costs to city, county, state and federal government for flood clean-up, ditch maintenance, and pipe and ditch installation can be reduced. The costs of dredging creeks, river and lake to remove sediments can be lowered. Similarly, on agricultural lands, a reduction of back-up flooding will decrease crop damage and loss of revenue to the farmer.

5. Improved Appearance

By molding landforms and carving meandering natural vegetative swales, berms, detention ponds, and other landscape elements, residential and commercial areas can be made more attractive.

6. Enhanced Property Values

The improved appearance and reduced potential for flooding and wet conditions and improved ecological conditions can serve to increase property values and the marketability of new development and agricultural activities.

D. Summary of Recommendations

The following are major recommendations provided throughout this Nine Springs Neighborhood Storm Water Management Plan to minimize storm water runoff, encourage storm water infiltration, prevent property damage and hazardous conditions, minimize soil erosion, reduce sediment and nutrient deposition in the storm water conveyance systems and E-Way, protect the quality of groundwater, protect the water supply aquifer, preserve the Nine Springs Creek E-Way Corridor as an asset to the community, and minimize the negative impact of existing and future storm water discharges to wetlands, springs, E-way, and the environment.

1. Natural Resources

Implement an Ecological Restoration and Management Program which includes:

- Restore vegetation habitat structure, biological and biogeochemical functions;
- Prepare selected sites for use of prescribed burning management;
- Eradicate problematic non-native plant species with prescribed burning and selective or non-selective herbicides on some species;
- Establish a policy of urban wildlife and human disruption of ecological system functions;
- Implement a maintenance and low-intervention program;

- ▶ Scheduling, monitoring and management for ecological restoration
- ▶ Specialized training for restoration management
- ▶ Ecological monitoring
- ▶ Reporting

2. Infiltration / Hydrogeology

- Provide sufficient infiltration and groundwater recharge to the maximum extent practical and feasible to ensure adequate spring flow and discharge to wetland areas;
- Achieve consistently high infiltration and shallow groundwater recharge rates with minimal maintenance by encouraging deep, continuous large-diameter macropores through the use of prairie and grass infiltration areas;
- Encourage agricultural practices that increase and protect the activity of worm-created macropores such as no-tilling, slot-mulching, and limited use of pesticides and herbicides;
- Encourage limited or no use of residential lawn fertilizers, pesticides and herbicide applications.

3. Storm Water Quantity

- Implement a regional storm water management system in lieu of individual on-site management systems;
- Preserve overland drainage routes for large storm event emergency overflows and conveyances;
- Utilize a 10-year frequency storm event for storm sewer pipe design and 100-year frequency storm event for overland drainage and detention basin design;
- Where feasible and practical, utilize open prairie and grass conveyance channels in lieu of storm sewer pipe systems;
- Discourage the use of concrete and riprap-lined channels;
- Where feasible and practical, storm water runoff quantity should be controlled with detention ponds designed for the 100-year post-development storm event and its discharge control released at the 10-year pre-development storm event runoff rates. The detention pond control structure should be

designed to control storm events less than the 10-year event at or below their pre-development runoff rates. At a minimum, detention ponds should store additional storm water runoff for all storm events due to development, and discharge at rates equivalent to pre-development runoff rates;

- Detention basins should be designed to limit their outflow rates to no more than the allowable capacity of existing downstream conveyance and storage system;
- Industrial and commercial high hazard facilities should provide individual on-site containment and storm water runoff pre-treatment systems prior to discharging off-site to the City storm sewer system and regional storm water management system;
- Encourage construction of grass and prairie grass infiltration systems in lieu of French Drain and other structures due to increased water quality benefits and lower long term operation and maintenance costs.
- Encourage construction of wet detention basin systems in lieu of dry detention basins due to increased water quality benefits and lower operation and maintenance costs;
- Make efficient use of open space by combining park systems with detention basin, infiltration areas, and storm water management systems.

4. Storm Water Quality

- Mitigate sediment discharge during construction by limiting and/or programming the area proposed for mass stripping and earthwork operations at a given time;
- Mitigate sediment discharge during construction by engineering, locating, and constructing temporary sedimentation basins and traps or permanent detention basins at the point of discharge from the construction site prior to discharge off-site; this should be done at the time of construction and prior to commencing any land-disturbing activities;
- Provide highest water quality and infiltration benefits, and lowest operation and maintenance costs by installing wet

detention basins, grass and prairie grass buffer and filter strips and swales, and constructed wetlands, and utilize existing wetlands;

- Most efficient wet detention pond is one that has a static water storage volume (permanent water pool) greater than or equal to the volume of runoff from a 2-inch storm event under full projected watershed development with a 25% increase for sediment storage;

5. Structural BMPs

- Multi-stage wet detention basins
- Constructed wetlands
- Infiltration basins/dry detention basins in conjunction with wet detention basins
- Riprap/gabions/geotextiles installation for heavily eroded drainageway and creek areas
- Unconnected storm water conveyance systems
- Grass and prairie grass vegetated buffer zones minimum 75 feet wide at wetlands and creeks
- Grass and prairie grass vegetated buffer zones minimum 25 feet wide at detention ponds
- Natural open land area drainage conveyance design
- Native vegetation for landscaping

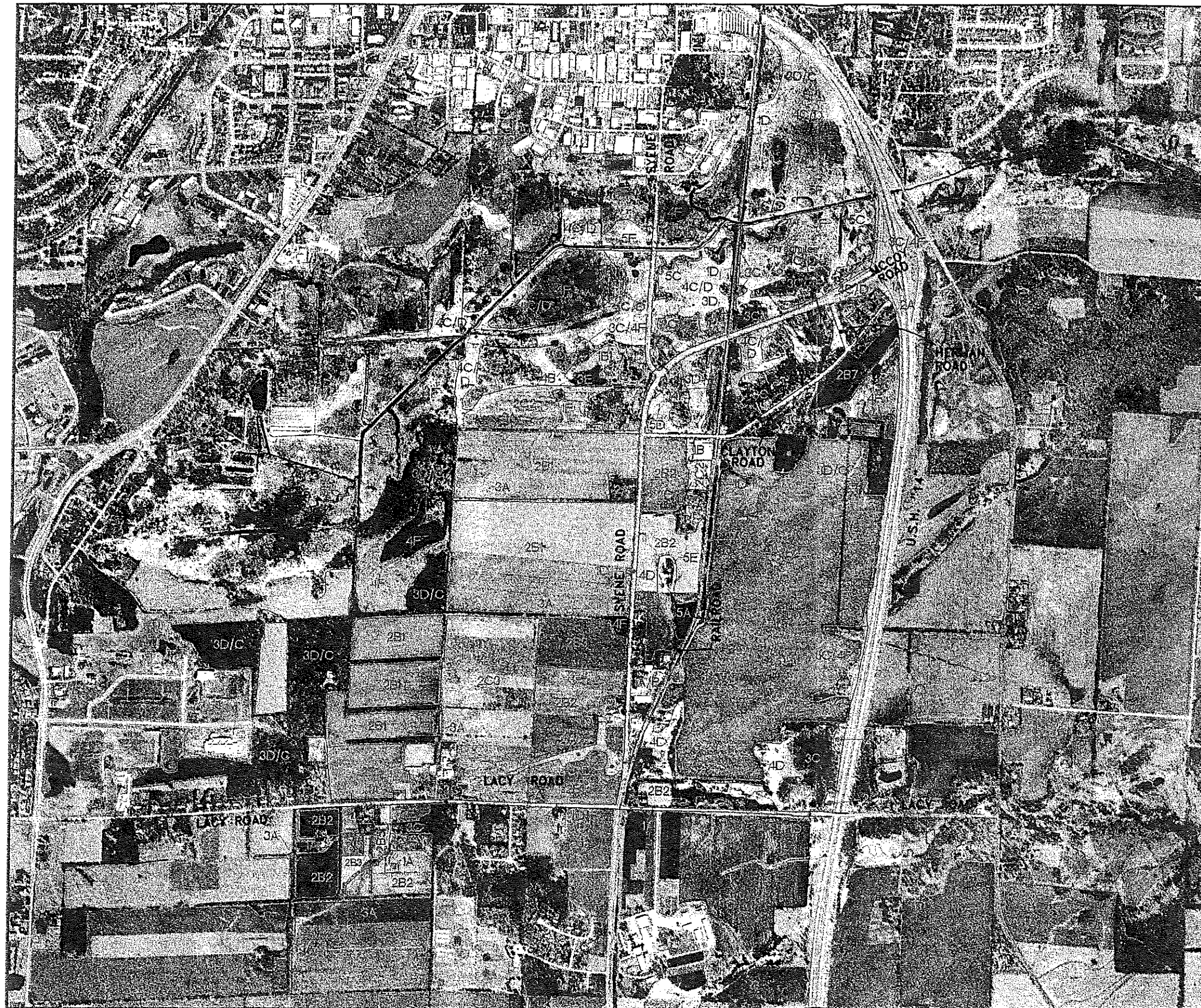
6. Non-Structural BMPs

- Pro-active lawn care practices
- Proper pet waste disposal
- Construction site erosion control practices
- Catch basin sumps and regular maintenance
- Regular street sweeping
- Agriculture land management practice
- Well head protection (ordinance)
- Comprehensive storm water management ordinance
- Public education and information programs
- Reduction of waste dumping in storm sewers
- Prohibit use of copper and galvanized materials for roofs and rain gutters
- Reduce building setbacks
- Reduce street width requirements
- Reduce parking requirements
- Encourage cluster developments
- Implement open space opportunities

7. Funding / Financing Options

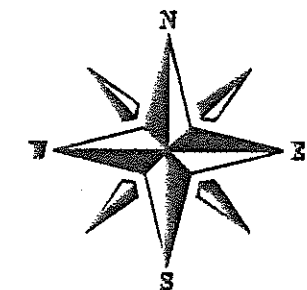
- State/federal grants and loans
- Development changes
- Fee-in-lieu of on-site detention/retention
- Special assessments
- Plan review and inspection fees
- Storm water service charges
- Taxation
- Bonding
- Storm water utility

Appendices



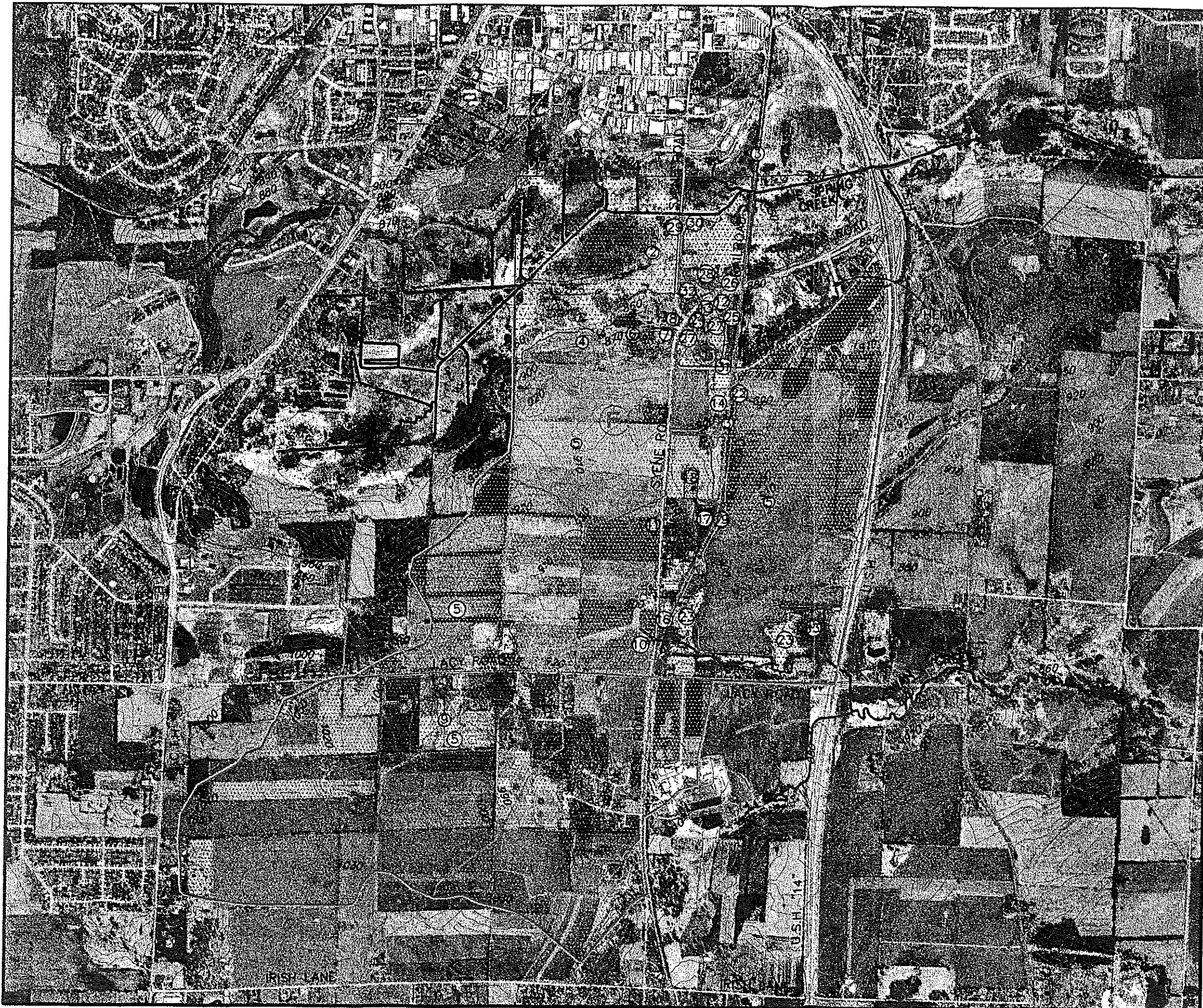
VEGETATION/LAND COVER TYPES

1. Developed Land
 - A. Residential
 - B. Commercial/Industrial
 1. Graded, not built land
 2. Rock quarry
 3. Landfill
 - C. Recreation land
 - D. Rail and Road Right of Way
 - E. Landscape planting
 1. Golf course fairway
 2. Golf course rough
 3. Mowed lawn
 4. Planted berm
 - F. Spoils pile
 - G. Compost management
 1. Row compost piles
 2. Pre-spread compost
 - H. Ecological buffer
2. Agricultural Land
 - A. Residence and outbuildings
 - B. Fields (cropped)
 1. Corn
 2. Beans
 3. Alfalfa
 4. Oats, winter wheat, rye
 5. Pasture
 6. Nursery
 7. Other
 - C. Fields (fallowed)
 1. Mowed
 2. Un-mowed
 3. Warm-season prairie grasses
 - D. Bare soil
 - E. Old field, tree and shrub regeneration
3. Forested and Savanna Communities
 - A. Tree line/fence row
 - B. Flood plain forest
 - C. Recently developed forest/brush
 - D. Oak savanna/barrens remnant
 - E. Plantation/orchard
 - F. Mesic forest remnant
 - G. Flatwoods remnant
4. Wetlands
 - A. Wet prairie remnant
 - B. Sedge meadow remnant
 - C. Cattail, tall emergent vegetation
 - D. Reed canary grass vegetation
 - E. Native forb-dominated remnant
 - F. Forested and shrub thicket
 - G. Formed wetland
5. Open Water/Drainages
 - A. Created pond/lake
 - B. River
 - C. Stream/creek
 - D. Spring/seep/fen
 - E. Natural pond/lake
 - F. Farm Ditch
 - G. Intermittent drainageway (non-wetland)
6. Upland Prairie Remnants
 - A. Mesic prairie remnant
 - B. Dry prairie remnant
 - C. Timbered prairie remnant
 - D. Buffer



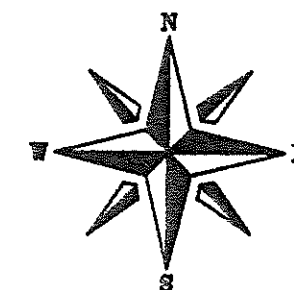
SCALE: 1"=1500'

VEGETATION LAND COVER TYPES
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
FIGURE NO. 1



LEGEND

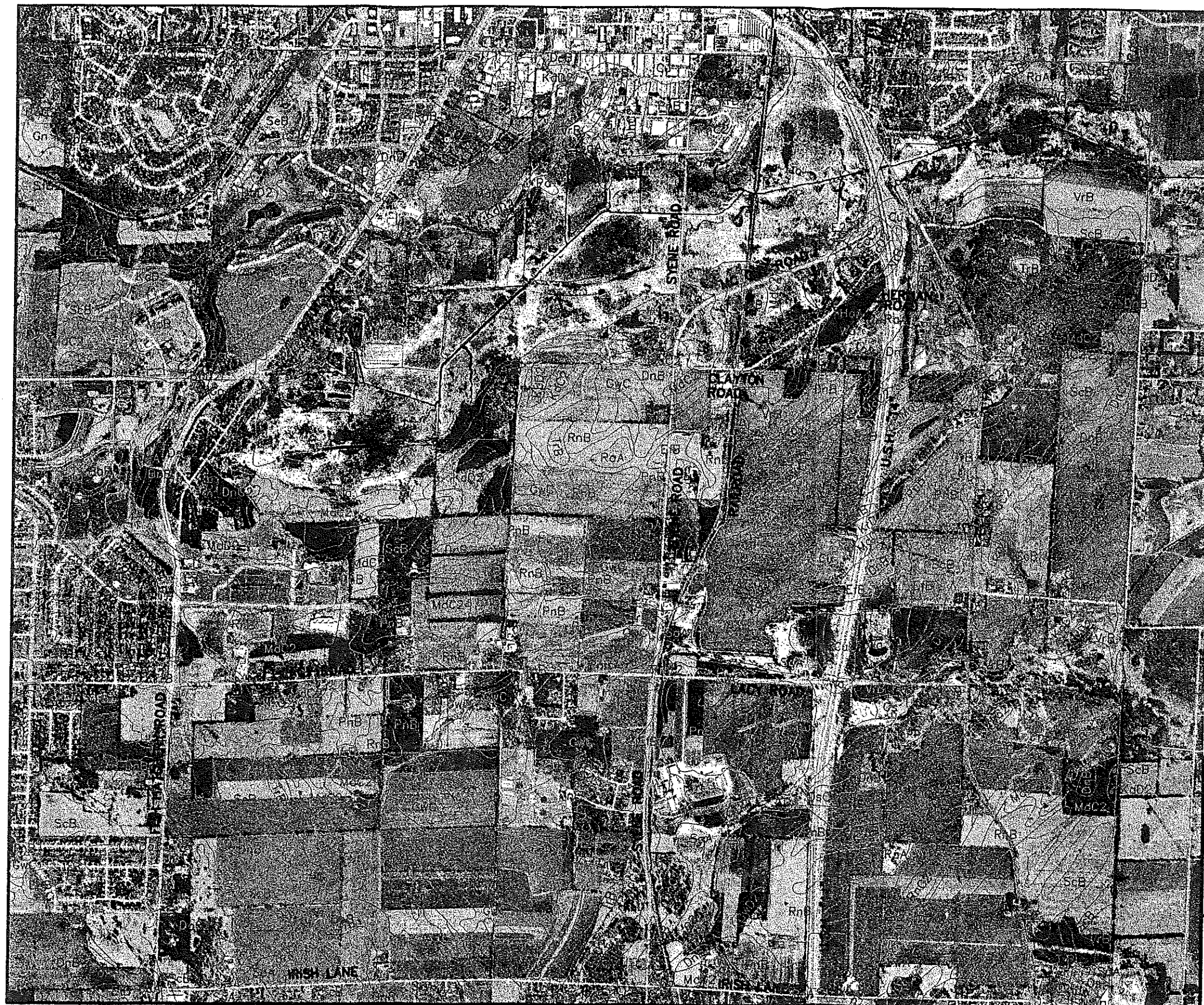
- NINE SPRINGS NEIGHBORHOOD WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- ~ NINE SPRINGS CREEK/SWAN CREEK/DRAINAGEWAY
-  DELINEATED WETLANDS
-  SUBWATERSHED DESIGNATION
-  10' CONTOUR
- ⑤ WETLAND I.D. LOCATION



SCALE: 1"=1200'

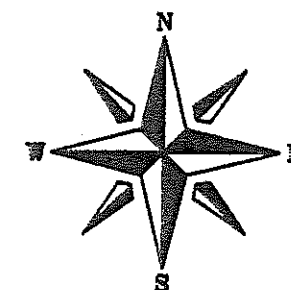
ROUTINE WETLAND DETERMINATION
I.D. LOCATIONS
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
FIGURE NO. 4

VIERBICHER
ASSOCIATES
6300 MINERAL POINT ROAD MADISON WI 53705 608-233-5500



NOTE:
SEE DANE COUNTY SOIL SURVEY FOR
SOIL SERIES DATA.

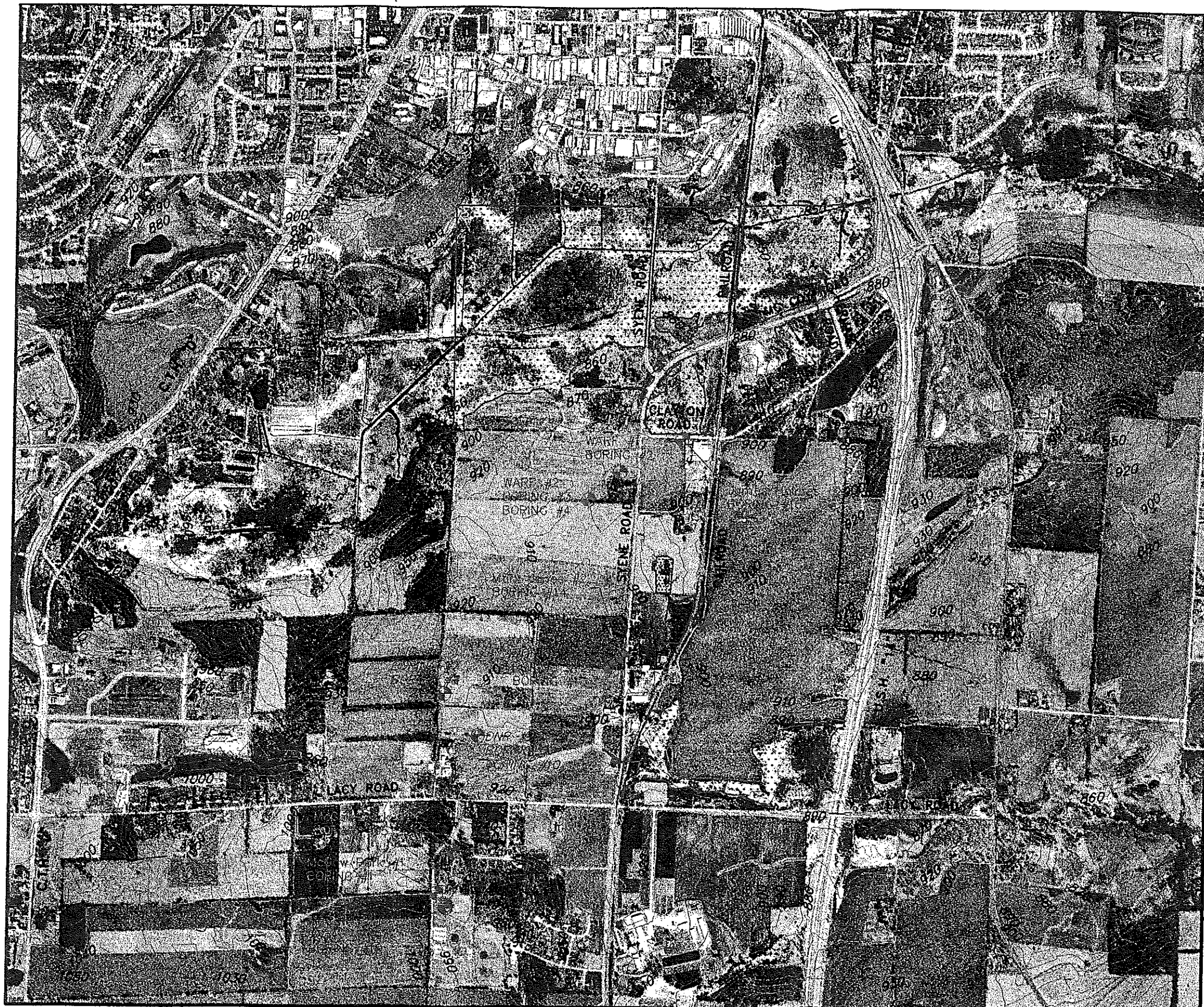
SOIL MAPPING DATA COMPILED FROM
DATA FROM DANE COUNTY LAND
INFORMATION OFFICE.



SCALE: 1"=1800'

USDA/SCS SOIL SURVEY MAP
FOR DANE COUNTY
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
MAP EXHIBIT NO. 1

 **VIERBICHER**
ASSOCIATES
8200 MINERAL POINT ROAD MADISON WI 53705 608-233-8800



LEGEND

James Holmes
BORING #16

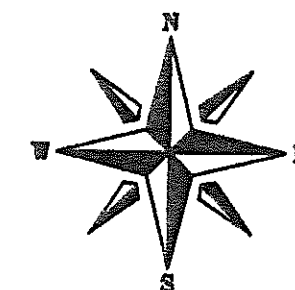
TEST HOLE LOCATION



DELINEATED WETLAND



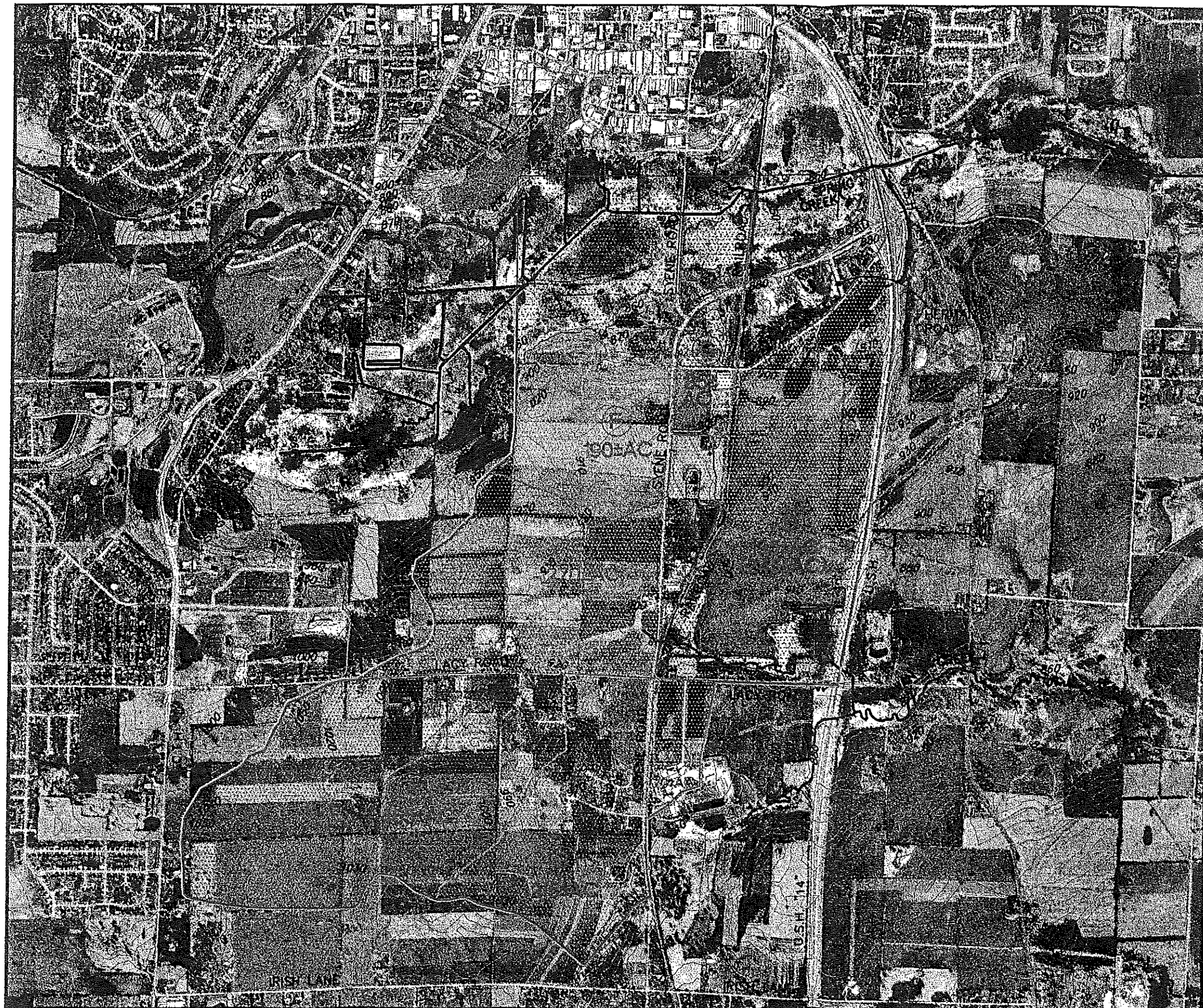
10' CCNTCUR



SCALE: 1"=1500'

PERMEAMETER TESTING LOCATIONS
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
MAP EXHIBIT NO. 2

VIERBICHER
ASSOCIATES
6200 MINERAL POINT ROAD MADISON WI 53705 608-233-5800



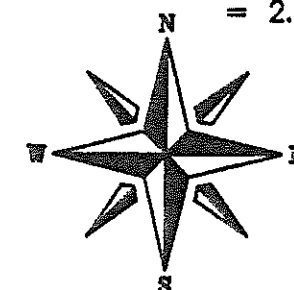
LEGEND

- NINE SPRINGS NEIGHBORHOOD WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- NINE SPRINGS CREEK/SWAN CREEK/DRAINAGEWAY
- DELINEATED WETLANDS
- SUBWATERSHED DESIGNATION
- 10' CONTOUR

* WETLAND AREA NOT INCLUDED IN ACREAGE

SUBWATERSHED A - 465± ACRES
SUBWATERSHED B - 215± ACRES
SUBWATERSHED C - 70 ± ACRES
SUBWATERSHED D - 245± ACRES
SUBWATERSHED E - 270± ACRES
SUBWATERSHED F - 190± ACRES*
SUBWATERSHED G - 35 ± ACRES*
SUBWATERSHED H - 215± ACRES

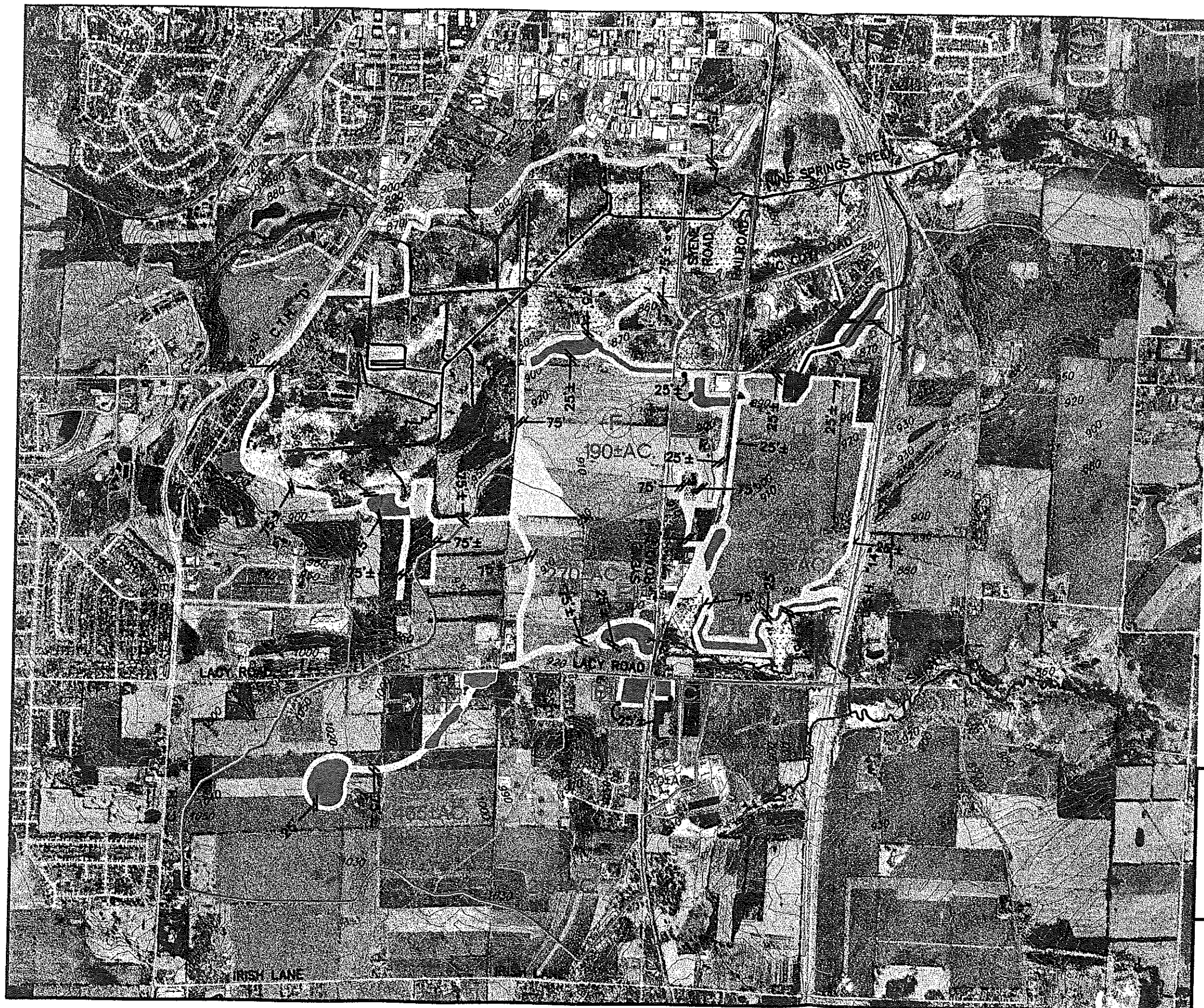
TOTAL WATERSHED = 1705± ACRES
= 2.66 ± SQ. MI.



SCALE: 1"=1800'

WATERSHED/ SUBWATERSHED/
SUBAREAS
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
MAP EXHIBIT NO. 3

VIERBICHER
ASSOCIATES
6200 MINERAL POINT ROAD MADISON WI 53705 608-233-5800



LEGEND

- NINE SPRINGS NEIGHBORHOOD WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- NINE SPRINGS CREEK/SWAN CREEK/DRAINAGEWAY



DELINEATED WETLANDS



SUBWATERSHED DESIGNATION



10' CONTOUR

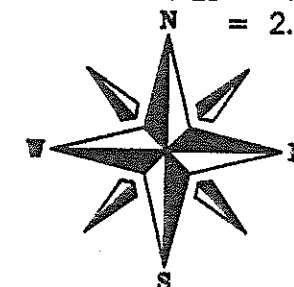


RECOMMENDED WET DETENTION WATER QUALITY / WATER QUANTITY PONDS

RECOMMENDED PARK / CONSERVANCY / OPEN SPACE PRAIRIE GRASS VEGETATION WATER QUALITY BUFFER AREAS.

- SUBWATERSHED A - 465± ACRES
- SUBWATERSHED B - 215± ACRES
- SUBWATERSHED C - 70 ± ACRES
- SUBWATERSHED D - 245± ACRES
- SUBWATERSHED E - 270± ACRES
- SUBWATERSHED F - 190± ACRES*
- SUBWATERSHED G - 35 ± ACRES*
- SUBWATERSHED H - 215± ACRES

TOTAL WATERSHED = 1705± ACRES
N = 2.66 ± SQ. MI.



SCALE: 1"=1800'

RECOMMENDED STORMWATER
MANAGEMENT FACILITIES
NINE SPRINGS NEIGHBORHOOD
STORM WATER MANAGEMENT PLAN
CITY OF FITCHBURG
MAP EXHIBIT NO. 4

VIERBICHER
ASSOCIATES
6200 MINERAL POINT ROAD MADISON WI 53705 608-233-3800