FULBRIGHT SPRING PROTECTION STUDY

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PHASE 1
FULBRIGHT SPRING
PROTECTION STUDY

Prepared for:

Watershed Committee of the Ozarks
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City Utilities of Springfield
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GLOSSARY OF TERMS

ASCE	American Society of Civil Engineers
BAT	Best Available Technology
BCT	Best Conventional Technology
BPT	Best Practicable Technology
BMP	Best Management Practice
CFR	Code of Federal Regulations
CSR	Code of State Regulations
CU	City Utilities of Springfield
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
MCL	Maximum Contamination Level
MGD	Million Gallons per Day
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NURP	National Urban Runoff Program
ppb	Parts Per Billion
PUD	Planned Unit Development
RFP	Request For Proposals
SARA	Superfund Amendments Reauthorization Act
SEF	Sensitive Environmental Features
SDWA	Safe DrinkingWater Act
TCE	Trichloroethylene
TSS	Total Suspended Solids
USGS	United States Geological Survey
UST	Underground Storage Tank
UV	Ultraviolet
VOC	Volatile Organic Compounds
WQCC	Water Quality Control Commission
WWE	Wright Water Engineers, Inc.

EXECUTIVE SUMMARY
PHASE I OF THE FULBRIGHT SPRING PROTECTION STUDY

I. PROJECT BACKGROUND AND GOAL

Fulbright Spring is located on the northern edge of Springfield, Missouri. The spring presently provides roughly 20 to 25 percent of Springfield's raw water supply annually. The spring has been used as a public water supply for over 100 years. The spring recharge area is approximately 28 square miles in size. The area is projected to rapidly urbanize, especially with the recent completion of the South Dry Sac Trunk Sewer.

Greene County, the City of Springfield, City Utilities of Springfield (CU), and the Watershed Committee of the Ozarks (the project sponsors) have specified that the basic goal for this evaluation is to take an initial step ("Phase I") towards the development of a comprehensive watershed protection plan for Fulbright Spring. The project sponsors hope to maintain, to the extent practicable, the existing water quality characteristics of the spring.

II. OVERVIEW OF MAJOR WORK TASKS

The following work tasks have been conducted by Wright Water Engineers, Inc.[1] (WWE) as part of the Phase I evaluation:

1. Obtain, organize and analyze existing hydrogeologic, climatic, and land use information and data and provide a general overview of the watershed.

2. Based upon the available information and data, define the Fulbright Spring recharge area and important hydrologic characteristics of this area. Define "gaps" in the data and suggest additional studies to refine the current level of understanding of the recharge area's hydrologic characteristics and areal extent.

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[1]The Wright Water Engineers, Inc. (WWE) consulting team for this study includes: Wright Water Engineers, Inc. (Denver, Colorado); Dr. Thomas N. Debo, P.E. (Georgia Institute of Technology); Dr. Edwin Herricks (University of Illinois); Palmerton & Parrish Consulting Engineers (Springfield, Missouri); and Mr. Joseph Wilson, P.E. (Rolla, Missouri). Independent review of WWE's findings was provided by Mr. Earl Shaver (State of Delaware), Mr. Eric Livingston (State of Florida), and Dr. Kenneth Thomson (Southwest Missouri State University).

3. Review existing spring water quality data and establish the relationship between rainfall-runoff events on the ground surface and corresponding spring hydrology and water quality.

4. Define potentially applicable spring water quality criteria to enable the study sponsors to select an appropriate regulatory strategy.

5. Define and assign initial ratings to "sensitive environmental features" (SEFs) in the recharge area.

6. Based upon existing and proposed land use characteristics, qualitatively project probable spring water quality, and hydrologic changes in the absence of mitigation strategies.

7. Define nonstructural best management practices (BMPs) for the recharge area.

8. Define structural BMPs for the recharge area.

9. Suggest potential approaches to monitoring.

III. SUMMARY OF STUDY RESULTS - SUSCEPTIBILITY OF THE SPRING TO WATER QUALITY DEGRADATION

The karst (limestone) terrain of the region creates a complex interaction between the surface and subsurface hydrologic regimes. The limestone weathers readily, forming sinkholes, caves, and other karst features. A shale layer (Northview) separates the lower, major water supply aquifer from the upper aquifer. A number of faults have been identified which, along with domestic water wells, provide a connection between the two aquifers. Fulbright Spring is a component of the upper aquifer.

The Fulbright Spring recharge area is shown on Drawings 1, 2, and 3. It is important to recognize that this is an approximate recharge boundary. Further studies are needed to more precisely delineate the recharge area, particularly on the western side.

Representatives of the CU have reported to WWE that historically, Fulbright Spring has been a reliable raw water supply (with respect to both quantity and quality) and that only conventional water treatment technologies have been necessary. WWE's review of the available raw water

quality data confirm this observation. CU staff and others have also noted that the spring has been used by the City of Springfield for over 100 years and that the recharge area was largely undeveloped for much of this time span.

One of the more important Phase I findings is that, from a water quality standpoint, Fulbright Spring responds to surface hydrological events more like a surface water source than a groundwater source. Numerous faults and fractures, over 180 sinkholes, and multiple losing stream reaches allow surface flows direct access to the shallow groundwater that sustains Fulbright Spring and result in a lack of natural water purification processes. For this reason, *the spring is highly vulnerable to degradation from activities on the ground surface.*

Available water quality data for Fulbright Spring clearly demonstrate that spring water quality degrades in response to rainfall-runoff events on the ground surface. For example, during and shortly after runoff events, there is a nearly immediate response of Fulbright Spring in terms of increased flow and increased concentrations of total and fecal coliform, turbidity, total suspended solids, and other water quality parameters.

The effects of land use changes on water quality are well described. Typically, development of a watershed results in an increase in impervious area that, in turn, increases the runoff ratio for precipitation. This increased runoff has two primary effects. First, there is a change in the channels transporting the increased runoff volume. This can include general channel instability, increased bank erosion and channel movement, and altered floodplain areal extent. Second, the runoff has the potential to transport increased loads of pollutants and contaminants. New sources of pollutants and contaminants are produced by development, and the potential for transport of these pollutants to receiving waters is increased.

The Springfield Planning Department projects substantial development in the Fulbright Spring Watershed over the next 20 years. Specifically, with a total drainage size of about 28 square miles (18,000 acres), about 5.9 square miles (3,800 acres) of new residential development and 2.2 square miles (1,400 acres) of new industrial/commercial construction is projected. Drawing 4, provided by the Planning Department, shows the projected land use for the year 2015. The approximate recharge area boundary is indicated by a dotted purple line.

Data collected by many cities demonstrate that as basin "percentage impervious area" increases, stormwater pollutant concentrations increase. For example, the results of the "National Urban Runoff Program" (NURP) demonstrate that typical urban stormwater contains elevated levels of

such constituents as nutrients, coliform, sediment, and metals. The NURP data also indicate that man-made organic compounds that are listed as EPA "priority pollutants" and/or are regulated under the federal Safe Drinking Water Act (SDWA) are often present. Runoff data collected by the City of Springfield as part of the City's National Pollutant Discharge Elimination System (NPDES) permit application process show elevated parameter levels also.

In October 1994, the CU Central Laboratory performed screening tests in areas around lower Pearson Creek for volatile organic compounds (VOCs). Levels of trichloroethylene (TCE) of 3.5 parts per billion (ppb) were found in the creek as well as 11.5 ppb in Jones Spring. Also found in Jones Spring were detectable levels of bromodichloromethane, chloroform, 1,1-dichloroethane, 1,1- dichloroethene, 1,1,1-trichlorethane, and tetrachloroethylene. Although this watershed is separate and distinct from the Fulbright Spring recharge area, the results are relevant as an indicator of how ground and surface water quality may be affected as the Fulbright Spring recharge area increasingly urbanizes.

Based upon the identification and ranking of "sensitive environmental features" (SEFs) in the Fulbright Spring recharge area (see Chapter 5), it is clear that the risk of degradation of Fulbright Spring water quality will increase as the recharge area develops, in the absence of carefully conceived runoff control measures. SEFs are defined as any definable source, transport pathway, or landscape feature associated with environmentally damaging conditions. By virtue of the many geologic features in the basin which permit rapid conveyance or entry of surface water into the shallow groundwater system (sinkholes, "losing" stream channels, fractures and faults, etc.), the basin is quite vulnerable to pollutants in runoff from urban and industrial areas (agricultural lands are excluded from this study).

WWE's evaluation of existing pollutant sources, transport paths, and geologic features that permit entry of surface flows into the shallow groundwater indicates that *there is already significant risk to spring water quality.* It is surprising that available spring water quality monitoring data generally show good water quality, and WWE has concluded that the remaining "safety cushion" in the recharge area is small. It should also be cautioned that "pulses" of pollutants are not easily seen in the monitoring of groundwater with such high flow velocities, and that additional wet weather "screening" data at Fulbright Spring (especially for target organic compounds) should be obtained.

A fundamental axiom of public water system management is that those drainage basins which serve as raw water supply sources should be left undeveloped and undisturbed to the maximum

extent practical. The Fulbright Spring recharge area already contradicts this axiom, and will to an even greater degree in the future as development increases. Consequently, to satisfy the goal of the study sponsors—spring water quality protection—*a strong watershed management program is essential.*

IV. AVAILABLE PROTECTION CRITERIA

Given that Fulbright Spring merits protection and that the source is vulnerable to degradation as the recharge area develops, the question arises: What regulatory framework or "target" should be established? To this end, Chapter 4 of this report, "Alternative Approaches for Establishing Protection Criteria," overviews water quality control philosophy, including historical perspective on the control of discharges to groundwater and surface water and options for establishing criteria for water quality standards.

The State of Missouri already has strong numeric groundwater quality standards that appear to apply to the basin. An option is to rigorously enforce these standards within the recharge area, including the potential regulation of certain stormwater discharges via effluent limitations or on the basis of compliance with existing groundwater standards. Due to the expense, complexity, and difficulty in maintaining such a rigorous approach, WWE recommends a more moderate regulatory approach, at least initially. Specifically, as defined and discussed below, a combination "nonstructural/structural BMP" regulatory strategy is recommended as the appropriate starting point for the recharge area.

V. BEST MANAGEMENT PRACTICES

In the course of conducting this Phase I level investigation, members of the WWE team have consulted over 100 reference books and articles on stormwater quality and watershed management. We have interviewed many recognized national experts. We have retained Mr. Earl Shaver, Director of Stormwater Management for the State of Delaware, and Mr. Eric Livingston, Director of Stormwater Management for the State of Florida, to independently review our findings.

Based upon our experience and research, a combination of *nonstructural* and *structural* "best management practices" or "BMPs" will be needed to effectively protect spring water quality. *Nonstructural BMPs* are practices such as public education, reduced use of pesticides/fertilizer on residential lawns, parks, golf courses, etc., and others that do not involve the construction of

structures. *Structural BMPs* are constructed facilities such as stormwater detention ponds and conveyance channels.

The broad elements of an initial watershed protection plan for the spring recharge area include:

1. Pollution prevention measures (source controls). The underlying principle is that it is less expensive to prevent pollutants from getting into stormwater than it is to remove them from stormwater.

2. Public/worker education and increasing the level of "awareness" in the basin. This makes people sensitive to, for example, over-fertilizing, inappropriate use of pesticides, improper waste disposal, etc.

3. Full utilization of the existing State of Missouri and Greene County erosion and sediment control, sinkhole and other pertinent ordinances. General and specific comments on existing regulations are provided in Sections 7.3.1, 7.3.2, and 7.3.3. These ordinances provide a good starting point, but, to be effective, adequate manpower must be provided to administer them.

   In addition, the probability of successfully protecting spring water quality will be increased if the City of Springfield adopts and enforces an erosion and sediment control program to complement the existing Greene County program.

4. Development and implementation of a comprehensive stormwater management program for the basin. A basin masterplan is needed.

5. Potential implementation of an impervious area limitation for the basin and utilization of "overlay zoning" in the vicinity of stream channels, sinkholes, and other important material features that are responsible for introducing surface flows into the groundwater.

6. Routine use of small, relatively inexpensive structural BMPs that are oriented towards slowing down runoff rates, minimizing directly connected impervious area, ponding stormwater to promote pollutant removal, etc. Grass-lined swales, dry detention ponds, etc. are examples of potential BMPs for this setting.

7. Adequate maintenance, monitoring, and enforcement.

8. Adequate funding and staffing for all of the above.

A. NONSTRUCTURAL BEST MANAGEMENT PRACTICES

As discussed at length in Chapter 7, the initial watershed protection program should emphasize a wide array of nonstructural practices, including:

1. Utilize existing ordinances to their fullest extent;

2. Practice "source controls" to limit the probability that pollutants will enter watercourses. Pesticide and fertilizer selection and application protocols are an especially good example;

3. Utilize innovative zoning techniques, including overlay zoning and impervious area limitations;

4. Acquire or otherwise promote buffer zones (limited or no development) around sensitive environmental features, such as sinkholes, losing channel reaches, defined fractures, etc;

5. Develop an effective plan for responding to and managing unforeseen spills;

6. Utilize the sensitive environmental features (SEFs) analysis procedure described in Chapter 5 to help guide decisions on land development; and

7. Increase the effectiveness of erosion and sediment control practices.

WWE has reviewed pertinent existing City of Springfield and Greene County ordinances and other policy documents that relate to water quality protection of Fulbright Spring. Greene County has erosion and sediment control, sinkhole and other ordinances that are generally well written and which provide a solid foundation for moving ahead with a watershed protection program. (This opinion is offered by a group of technical consultants, and a thorough legal and financial review of the ordinances is essential.) WWE strongly recommends that adequate funding be provided to carry out these ordinances to the maximum extent feasible because this is one of the more direct and effective means available for protecting the spring.

In addition to reviewing existing ordinances/policies, WWE has prepared a memorandum entitled: "Initial Review of Source/Nonstructural Best Management Practices That Potentially Apply to the

Fulbright Spring Recharge Area" (Appendix 4). An array of potential nonstructural BMPs are discussed in detail in this report.

The acquisition of buffer zones around important geologic features in the recharge area will be an important technique to adopt for protection of spring water quality. The study sponsors have asked WWE to provide an opinion on whether it would be valuable for the City/County to acquire certain critical natural features within the spring recharge area. WWE is not prepared to offer definitive recommendations in this regard during Phase I; however, based on the analyses conducted to date, WWE recommends that this should be considered for any area near losing stream sections, particularly around the South Dry Sac River from the Valley Water Mill to "H" Highway. Additionally, any area immediately surrounding sinkholes should be considered particularly sensitive. The new policy by the City of Springfield prohibiting development within the 100-year flood storage zones for sinkholes will help to accomplish water quality objectives. Also, minimum setbacks should be carefully considered. For example, in Florida stormwater systems and on-site wastewater systems are typically set back 100 to 300 feet from critical areas such as stream channels and sinkholes.

Land use controls such as minimum setbacks, buffer zones, open space areas, critical acquisition areas, etc. could be used in conjunction with "overlay zoning." Impervious area limitations could be implemented as an overlay zoning map. Many successful stormwater quality programs have impervious area limitations and this should be carefully considered for the Fulbright Spring recharge area during subsequent study phases. Rather than setting overall impervious area limits throughout the recharge area, this overlay zoning would allow for the most restrictive limits on those areas where pollution control is most important. Impervious area caps of, for example, 20 percent can be achieved with wise land use planning and cooperation between the development community and local governments. It appears to WWE that local planning practices are advanced and that the basin can be developed in a way which provides reasonable opportunities for land developers while also protecting water quality.

The SEF procedure (Chapter 5 and Appendix 1) developed by WWE for this assignment readily lends itself to making land use decisions in the recharge area. The value of the SEF procedure is that it quantitatively accounts for the fact that any given site has unique water quality influence potential by virtue of: (1) potential pollution sources that will be present, (2) proximity to conveyance channel, and (3) proximity to geologic features that will permit entry of surface flows into the groundwater system that sustains the spring.

Minimizing the amount of land which is cleared at any one time is perhaps the most effective erosion and sediment control practice. WWE emphasizes the needs to: (1) fully implement and maintain the Greene County erosion/sediment control program that has been established and (2) have the City of Springfield implement and maintain a comparable program. A recent study noted by Mr. Earl Shaver in Delaware shows that the principal reasons for poor implementation of erosion control programs are inadequate staffing, funding, and political support. This is the foundation of a comprehensive stormwater quality management program for the recharge area. Because there is a direct connection between surface flows and the spring, total suspended solids levels at the spring increase during wet weather conditions. This further argues for strong erosion and sediment control.

The Fulbright Spring watershed protection plan must account for *both* construction and post-construction conditions. It is not adequate to focus solely on newly developing areas once they have been constructed and once the ground has been stabilized. To the contrary, it is also necessary to assure that during the land development process, when soils have not been stabilized, adequate erosion and sediment control practices are in place to strictly limit the amount of sediment that enters the drainage system, and ultimately into the shallow aquifer in Fulbright Spring. Although sediment from construction sites will not normally contain chemical compounds that would pose water treatability concerns (such as organic compounds), high levels of sediment in runoff from construction sites can affect the hydrology of the spring and can lead to increased treatment costs to remove suspended solids and turbidity. Furthermore, the surface streams in the recharge area are adversely affected by sediment-laden flows. Chapter 7 of this report comments on the adequacy of the existing erosion and sediment control practices in Springfield and Greene County.

B. STRUCTURAL BEST MANAGEMENT PRACTICES

Structural BMPs will be necessary to complement nonstructural controls during both construction and post-construction conditions. WWE's suggested initial approach is to call for the routine implementation of small, relatively inexpensive and easy-to-maintain BMPs, such as "slow flow" grass-lined channels and on-site dry detention ponds that are incorporated into the landscaping plan.

The basic intent of these practices is to "disconnect" impervious surfaces, slow down the rate of runoff, promote stormwater storage, and enhance the interaction of stormwater with vegetation. All of these actions reduce pollutant loading to receiving waters. Facilities of this kind should

be incorporated into new industrial, commercial, and residential developments, and ample evidence demonstrates that this can be accomplished without imposing a burden on developers and in a way which is aesthetically pleasing. The key to the success of such measures is that they are designed to address only a small amount of storm runoff (in contrast to drainage/flood control BMPs) that contains the majority of the pollutant load. Consequently, these can be readily incorporated into a development plan.

WWE's evaluation indicates that it is presently not feasible to implement larger BMPs that would be publicly maintained. Although there are many advantages to regional facilities over numerous, smaller "on-site" facilities, funding is not now available. There is clearly the need to move ahead with BMP implementation, however, so the current focus needs to be on on-site BMPs.

Properly constructed and maintained on-site BMPs in association with nonstructural controls may be adequate to maintain spring water quality, although monitoring data over time (as the basin develops) may show the need for regional BMPs in strategic locations.

The "treatment train" approach to structural BMPs should be emphasized. That is, control measures should be placed in series to maximize pollutant removal. In newly developing areas, it should be quite feasible to minimize "directly connected impervious area," and this alone will represent an important step towards water quality protection. Infiltration practices need to be used with great caution in the spring recharge area due to the high potential for pollutants to directly enter the groundwater system.

The WWE Technical Memorandum entitled: "Initial Review of Structural BMPs That Potentially Apply to the Fulbright Spring Recharge Area" (Appendix 7) provides detailed descriptions of multiple BMPs that are potentially applicable in the recharge area. The advantages and disadvantages of the BMPs are described within the text. Their potential applicability to the Springfield area is discussed only briefly and this is an important limitation that will need to be addressed in subsequent studies. All of these practices require routine and non-routine maintenance to sustain their effectiveness, and this must be included in budgeting or the BMP will likely fail.

WWE emphasizes that strong water quality protection actions now can reduce or at least forestall the need for large capital-intensive and maintenance-intensive BMPs. If alternative control strategies are not implemented soon, however, or if they do not prove effective (based on spring monitoring data), more intensive structural BMPs would be required to protect spring quality.

VI. ASSESSMENT AND COMPLIANCE MONITORING

Monitoring will be an essential component of the Fulbright Spring watershed protection program. Much valuable information on the effectiveness of structural and nonstructural BMPs in this setting could be gained by implementing and monitoring the effectiveness of pilot projects in the recharge area. The City, County, CU, and Watershed Committee will need to carefully coordinate monitoring to avoid redundancy and to promote cost effectiveness. Representative monitoring objectives include:

1. Monitoring is necessary to fill "gaps" with respect to the boundary of the spring recharge area and other hydrologic, hydrogeologic and biologic characteristics of the recharge area to create a baseline database. This is discussed in detail in Section 2.6.

2. The monitoring of spring quantity/quality characteristics needs to continue. It would be desirable to analyze more frequently for some subset of EPA's Priority Pollutants, especially under wet weather conditions, because data of this kind are currently limited. The most effective way to determine the overall effectiveness of the watershed management plan is to monitor spring quality. If certain contaminants begin to appear, and/or if "trend analysis" shows increasing pollutant concentrations, the structural and nonstructural controls will need to be strengthened. Adequate spatial and temporal frequency of monitoring is needed.

3. There are many erosion and sediment control BMPs that have been implemented in Greene County, and the comparative effectiveness of these BMPs should be defined with actual data during wet weather conditions.

4. More intensive monitoring of pilot stormwater quality BMPs such as grass-lined conveyances, wet and dry detention ponds and others should be performed so that design criteria can be provided.

5. For new land developments, it would be desirable to specify limited stormwater BMP monitoring requirements. This would promote proper design, installation and maintenance of BMPs.

VII. CONCLUSIONS

1. The goal of the project sponsors is to maintain, to the extent practical, the existing water quality characteristics of Fulbright Spring. Unless watershed protection strategies are implemented, this goal will not be attained.

2. It is inevitable that water quantity and quality changes will occur in the spring recharge area as urbanization continues. It is not possible to stop urbanization, but it is feasible to mitigate adverse impacts and to allocate the costs for this mitigation to those responsible and to those that will obtain the benefits.

3. As with most environmental problems, it is easier and more cost-effective to implement appropriate management techniques before major problems occur than to correct problems after damages are done. Water quality control in the spring recharge area is an excellent example of this. Keeping sediment on construction sites, preventing pollutants from entering local drainage systems, educating citizens on the proper use of potential pollutants, etc., are easier to implement and less costly than removing pollutants within the drainage system or at the water treatment plant.

4. The longer action is delayed, the higher the associated costs will be to provide adequate protection of the recharge area.

5. Aggressive implementation of relatively simple, inexpensive source control/pollution prevention strategies and the consistent application of small, inexpensive structural BMPs *now* will assuredly reduce the need for large, regional BMPs that are expensive in terms of land required and capital, operation/maintenance and monitoring costs. Small-scale structural BMPs, although much more numerous than regional ones, can often be made part of landscaping plans, such that the cost of implementation is minimal. Ideally, they will be designed on a site-specific basis.

   Monitoring will be necessary to assure that this strategy adequately protects the water supply.

6. Education of watershed residents and business employees should be the center of all actions related to a comprehensive program for protection. Simply stated, if people *regularly think* about the need to prevent pollutants (i.e., oil, gasoline, pesticides, solvents,

paint, fertilizers, pesticides, etc.) from entering *their water supply*, pollutant loading to Fulbright Spring will be lowered; perhaps significantly so.

7. Although not needed immediately, master drainage planning would be valuable. The sooner that this is started, the sooner basin-wide protection can be provided. The master drainage plan should be closely linked to the ongoing land use planning process. Also, to properly account for variable risk levels in the basin, the master drainage plan should be based upon a modified version of the "sensitive environmental feature analysis" procedure developed for this study area. The masterplan should encourage site-specific flexibility and should be "user-friendly," including a database and a geographic information system.

   Since developing a masterplan will take time, some measures should be enacted before the masterplan is completed, such as impervious area limitations and implementation of non-structural and some structural BMPs. This will reduce further degradation of the local water quality.

8. Engineering and technical design guidance (perhaps in the form of a Stormwater Criteria Manual) will be needed so that proper designs can become an integral part of local development design.

9. Due attention will need to be paid to these subjects:

   a. financing;

   b. acquiring "buffer zones" in strategic locations;

   c. improving local sediment and erosion control practices;

   d. implementing "source controls" (e.g., removing "illicit connections," pollution prevention and spill prevention and response plans for businesses, strict pesticide protocols for golf courses, parks, etc.) that maximize return on investment;

   e. fully implementing and monitoring city and county regulations that call for stormwater detention for both frequent and infrequent storms, such that historic peak discharges are not exceeded following full development;

f. determining the optimal design rainfall for water quality purposes (i.e., the "capture volume"); and

g. specifying conditions under which infiltration can and cannot be used for stormwater quality management, given the constraints of this karstic basin.

Perhaps the most important point to be made from this study is that, despite the significant potential for water quality degradation of Fulbright Spring, the use of relatively inexpensive nonstructural and structural BMPs should be effective in maintaining spring water quality, but *only* if such BMPs are: (1) instituted *before* problems occur, (2) implemented *intensively*, and without "cutting corners," (3) designed to account for the variable risk levels that characterize any given development site, and (4) thoroughly monitored and maintained. Public and worker education, source controls, minimizing impervious areas, on-site structural practices, and other BMPs have been effective in other watersheds where implemented on a *preventative* rather than *reactive* basis. More expensive large-scale structural BMPs will be necessary if these initial measures are not taken in a timely manner.

VIII. RECOMMENDATIONS FOR PHASE II OF WATERSHED PROTECTION PLAN

1. Local ordinances and regulations should be reviewed and revised to provide the legal measures needed for recharge protection. Those regulations already in effect which will help to protect spring water quality should be rigorously enforced. These include, for example, the City's new policy prohibiting development within the 100-year flood volume storage zones associated with sinkholes. Considerable guidance from City/County legal, financial, and administrative staff is necessary here. The City should adopt an erosion control ordinance to parallel the County's program.

2. Funding alternatives for the implementation and management of the watershed plan should be examined now and measures taken to provide this funding in the near future. When funding is made available, prepare a Water Quality/Quantity Masterplan to guide the decision-making process and to prioritize expenditures.

3. A refined delineation of the spring recharge area is essential. Any regulatory program must have this as its starting point. Dr. Kenneth Thomson and Mr. Fred Palmerton can provide the details of how this delineation should be conducted.

4. Initiate the public participation process, now that an adequate foundation has been established. It is particularly important to involve special interest groups and those in the community with special knowledge.

5. Additional monitoring is necessary, as described herein. Further data are needed to establish an acceptable baseline database, so that the effectiveness of controls can be assessed. Three examples of monitoring information needs are:

   a. characterization of wet-weather water quality at Fulbright Spring, particularly with respect to organic compounds regulated by the SDWA;

   b. pollutant removal efficiencies for small, relatively inexpensive structural BMPs; and

   c. a more accurate hydrologic mass-balance for the recharge area can be obtained for a modest investment, and this would assist in the decision-making process.

6. Adjust the SEF methodology developed for this study so that it can routinely be used in land use decisions and in defining constraints and design guidelines for proposed development projects. This approach offers the best opportunity for integrating risk assessment into the watershed protection program, and this is desirable.

7. Carry the structural/nonstructural BMP evaluation to the next level of detail to enable actual implementation (if appropriate) of such measures as: impervious area limitation; overlay zones; minimum buffer zones in vicinity of defined transport paths and geologic features; acquisition of sensitive features; design criteria for structural BMPs; and others. All further evaluation and implementation of nonstructural and structural BMPs should adhere to the recommendations of Chapters 7 and 8 of this report.

   It is important to define the optimal "balance point" between nonstructural and structural BMPs. It will also be important to have *specific written guidelines* for parties that intend to develop land in the spring recharge area—*what they need to do, when and with what follow-up.*

8. Implement pilot projects in the basin to test the effectiveness of the kinds of structural and nonstructural controls described herein.

9. As discussed at length in Chapter 4, WWE and the project sponsors have determined that the spring protection program should start with the widespread implementation of structural and nonstructural BMPs. Based on many technical and non-technical factors, WWE and the project sponsors concluded that it would be premature and unrealistic to ask land developers to comply with numeric discharge limitations for target constituents or to base a new regulatory program on compliance with numeric groundwater standards. Nevertheless, it is imperative to recognize that ultimately, a BMP-based regulatory program may not be adequate to meet the goal of strictly limiting spring water quality degradation; numeric standards may be necessary. This is why continued monitoring of Fulbright Spring is vital.

10. Legal, financial, administrative, and political input on the various measures under consideration must be obtained.

11. After receiving appropriate input from the public, City/County staff, elected/appointed officials, and others, *it is essential to begin to actively implement measures that will help to protect spring quality.* Although further engineering and legal work is necessary during Phase II of the spring protection study, this Phase I report provides many specific recommendations that can be acted on immediately.

The recommendations listed here are the most important ones offered by WWE. We emphasize, however, that additional recommendations, particularly those involving a higher level of detail, are provided within the report itself.

CHAPTER 1
STUDY PURPOSE AND BASIN OVERVIEW

1.1 STUDY PURPOSE

The purpose of this study is to take an initial step ("Phase I") towards the development of a comprehensive watershed protection plan for Fulbright Spring, which serves as an important raw water supply for the Springfield metropolitan area. The project sponsors hope to maintain, to the extent practicable, the existing water quality characteristics of the spring.

1.2 REPORT ORGANIZATION

CHAPTER 1: STUDY PURPOSE AND BASIN OVERVIEW

Overview of the study purpose and organization, brief discussion of the geography, soils, and climate of the recharge area.

CHAPTER 2: GEOLOGY, HYDROLOGY, AND IDENTIFICATION AND RATING OF SENSITIVE ENVIRONMENTAL FEATURES

Description of the identification and ranking system for sensitive environmental features (SEFs) developed for the study. General description of the geologic and hydrologic characteristics of the recharge area, along with a summary of data gaps and recommendations for further information collection and analysis.

CHAPTER 3: FULBRIGHT SPRING WATER QUALITY

Description of aquifer and spring characteristics and discussion of existing water quality data from Fulbright Spring and other sources, including City of Springfield National Pollutant Discharge Elimination System (NPDES) monitoring.

CHAPTER 4: ALTERNATIVE APPROACHES FOR ESTABLISHING PROTECTION CRITERIA

Historical discussion and analysis of water quality control approaches and options for the Fulbright Spring protection area. Conclusions include specific recommendations for Fulbright Spring.

CHAPTER 5: SENSITIVE ENVIRONMENTAL FEATURES

Based on the white paper report on SEFs, this describes the identification and ranking process of existing features, as well as a description of how this procedure could be used for analysis of future development.

CHAPTER 6: PROJECTED CHANGES IN SPRING WATER QUALITY

Based on existing water quality data, hydrogeologic conditions, and experiences elsewhere, a qualitative analysis of the degradation of water quality that may occur with development in the recharge area.

CHAPTER 7: NONSTRUCTURAL BEST MANAGEMENT PRACTICES

Descriptions, analyses, and recommendations for nonstructural best management practices (BMPs) that may have application to the Fulbright Spring protection area. Recommendations are included for nonstructural BMPs that should be immediately implemented as well as those which should become part of an overall water quality management plan.

CHAPTER 8: STRUCTURAL BEST MANAGEMENT PRACTICES

Descriptions, analyses, and recommendations for structural best management practices that may have application to the Fulbright Spring protection area. These include immediately implementable small-scale BMPs as well as larger regional BMPs for possible future implementation.

Appendices are attached which provide technical details on many of the analyses that are presented in the main text. Although not critical to an understanding of the report, they do

provide significant background information to supplement the recommendations and conclusions drawn.

1.3 COMPOSITION OF THE WWE STUDY TEAM

The following individuals were the leading contributors to this Phase I evaluation of Fulbright Spring:

1. Jonathan E. Jones, P.E., is a Vice President with Wright Water Engineers, Inc. (WWE) in Denver, Colorado. Mr. Jones is the overall project manager for this Phase I study. He has extensive experience with watershed management. He is the Chairman of the American Society of Civil Engineers (ASCE) Urban Water Resources Research Council and is the chairman of the committee that prepared the ASCE/Water Environment Federation *Manual of Practice for the Design and Construction of Urban Stormwater Management Systems*. Mr. Jones regularly publishes and teaches continuing education classes on the subjects that are pertinent to the Fulbright Spring Protection Study.

2. Dennis Bagenstos, Civil Engineer with WWE, has worked closely with Mr. Jones on the preparation of this report. Mr. Bagenstos has very strong work experience and academic background in all facets of watershed management and has recognized expertise in water quality regulation, evaluation and monitoring.

3. Dr. Thomas N. Debo, P.E., is the Associate Dean of Architecture at the Georgia Institute of Technology in Atlanta, Georgia. Dr. Debo is recognized as one of the top urban water resources planners in the United States today. However, his greatest strength lies in the fact that he is also a professional engineer with outstanding experience in computer modelling and facility design, such that he has managed to marry planning and engineering. Dr. Debo's many professional publications on ordinances, community reaction, facility acceptance/rejection issues have been widely distributed. He is also the author of two leading reference books on stormwater management.

4. Dr. Edwin Herricks is on the faculty of the Department of Civil and Environmental Engineering at the University of Illinois in Champaign-Urbana. Dr. Herricks is recognized as one of the foremost authorities in the world today on how aquatic ecosystems respond to wet weather conditions. He is a senior advisor/consultant to the U.S. Environmental Protection Agency (EPA) in Washington, D.C. on receiving water

issues associated with combined sewer and separate storm sewer discharges. He is frequently invited to speak around the United States on this subject. In the same way that Dr. Debo has distinguished himself by combining the fields of planning and engineering, Dr. Herricks has distinguished himself by combining the degrees of biology and engineering.

5. Fred Palmerton, P.E., is the President of Palmerton & Parrish Consulting Geotechnical Engineers in Springfield, Missouri. He is highly regarded as one of the top consulting engineers in Springfield and was recommended to WWE by many different parties as a key consultant to have on the WWE team to provide proper perspective on issues that are important to Springfield. Mr. Palmerton has conducted dozens of assignments in the Fulbright Spring recharge area and is well-acquainted with the hydrogeology of the region. He is the co-chair of the Citizen Stormwater Advisory Committee.

6. Joseph Wilson, P.E., is currently on the faculty in the Department of Civil Engineering at the University of Missouri-Rolla. Prior to moving to Rolla, Mr. Wilson was one of the most highly respected stormwater consulting engineers in Springfield, via his ten years with Scott Consulting Engineers. He has considerable expertise in facility design and he knows what will work and what will not work in Springfield. He is recognized as one of the leading hydrologic and hydraulic modelers in Springfield. Mr. Wilson's area of instruction at Rolla is presently focused on urban hydrology.

In addition, WWE has contracted the following individuals for peer review and expert analysis of this study:

7. Mr. Earl Shaver, Administrator for Stormwater Management and Sediment and Erosion Control for the State of Delaware. Mr. Shaver is well-known for his work in stormwater quality management in the Chesapeake Bay watershed as well as for his numerous papers written on stormwater quality management.

8. Mr. Eric Livingston, Environmental Administrator for the Florida Department of Environmental Regulation. Mr. Livingston has also written numerous papers and texts on stormwater management practices for water quality enhancement.

9. Dr. Kenneth Thomson, professor of geology at Southwest Missouri State University. He has conducted numerous studies of the geology and hydrogeology of the Fulbright Spring

recharge area and is recognized as the foremost authority on dye trace studies used to help define the perimeter of the recharge area.

Additionally, WWE wishes to emphasize the outstanding assistance that has been provided by the study sponsors from start to finish on this assignment. Members of the Watershed Committee of the Ozarks, Greene County, and City of Springfield have gathered reports and data, made observations in the field, provided referrals, and provided excellent comments on draft text. WWE thanks all of the relevant people for their help. The report that has emerged is truly reflective of a cooperative effort.

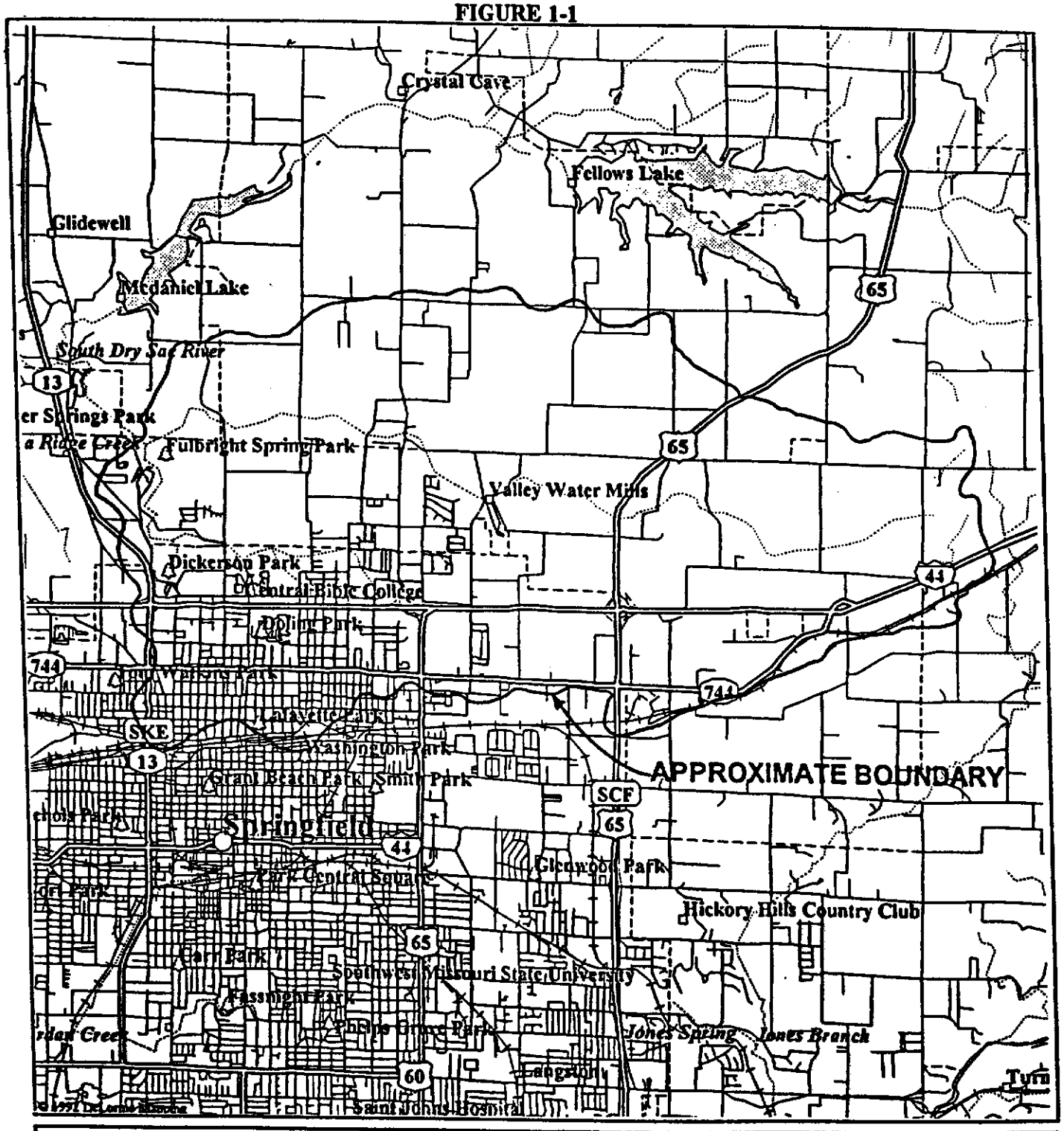
1.4 WATERSHED MORPHOLOGY

Fulbright Spring is located at 37°22'15" north latitude and 93°18'36" longitude. It is part of the Missouri River drainage basin. The approximate recharge area for Fulbright Spring is shown on Drawings 1, 2, and 3 as well as in Figure 1-1. The recharge areas shown are essentially the surface watershed boundaries for the South Dry Sac River and Pea Ridge Creek upstream of their confluence, modified as suggested by Dr. Kenneth Thomson, geologist, to reflect known characteristics of the recharge area. The terrain is generally rolling hills with gentle slopes in the upland regions with steeper slopes near the streams. Sinkholes and reaches of losing streams are common throughout the recharge area.

The recharge area is designated as approximate because of the complex interaction between the surface and subsurface hydrologic systems. The karst topography of the region precludes a precise delineation of the recharge area with the known data. There has been at least one dye trace conducted that shows a possible connection with the karst complex northwest of Springfield. Further study is warranted to better define the actual recharge area. Table 1-1, Spring Recharge Watershed Areas, lists the respective areas of each surface watershed.

Elevations within the recharge area range from 1,100 feet to 1,460 feet above mean sea level (United States Geological Survey [USGS] datum). The South Dry Sac River has a gradient of 33 feet per mile and Pea Ridge Creek has a gradient of 44 feet per mile. These gradients are high enough to result in erosive stream velocities. Cut banks are common and the stream beds are generally gravel and small cobbles. Overland slopes in the upland regions of the watershed are typically 2.0 to 2.5 percent.

FIGURE 1-1



WRIGHT WATER ENGINEERS, INC. 2490 W. 26TH AVE. 100A DENVER, CO 80211 (303)480-1700	DRAWN DSS CHECK DJB DATE 1/95 SCALE 1 : 87,500	**FIGURE 1-1** **APPROXIMATE BOUNDARY OF THE FULBRIGHT SPRING RECHARGE AREA**

TABLE 1-1
SPRING RECHARGE WATERSHED AREAS

Location	Area (square miles)
Valley Water Mill Reservoir	4.73
South Dry Sac River at confluence with Valley Water Mill	13.50
South Dry Sac River at swallow hole immediately downstream of Valley Water Mill	15.39
South Dry Sac River immediately upstream of confluence with Pea Ridge Creek	21.80
Pea Ridge Creek immediately upstream of confluence with South Dry Sac River	6.67
South Dry Sac River at confluence with Pea Ridge Creek	28.46

1.5 SOILS

Predominant soil types in the recharge area are the Wilderness and Goss cherty silt loams and the Needleye silt loam series. Soils data are from the *Soil Survey of Greene and Lawrence Counties, Missouri* (USGS 1982). The Wilderness and Goss series is typically found on the tops and sides of ridges in upland areas. Needleye soils are also upland soils found primarily on tops and sides of broad ridges. All three soil units have fragipans at depths of 18 to 36 inches. Wilderness and Goss soils have surface layers averaging 8 to 16 inches in thickness and have a permeability of 2.0 to 6.0 inches per hour. The Wilderness surface soil has a unified soil classification of SM-SC, SC, SP-SC, and GC. The fragipan has a permeability of 0.2 to 0.6 inches per hour that restricts the downward movement of water often resulting in a perched water table. The Goss surface soil has a unified soil classification of ML, CL, CL-ML, ML.

Needleye silt loam has a surface layer with a lower permeability of 0.6 to 2.0 inches per hour. The unified soil classification for Needleye soils is CL and CL-ML. The fragipan permeability is similar to the Wilderness and Goss series fragipan.

The recharge area is approximately 48 percent hydrologic soil group B, 46 percent hydrologic soil group C, and 6 percent hydrologic soil group D. The Soil Conservation Services's[2] *National Engineering Handbook* (USGS 1985) defines hydrologic soil groups as follows:

Group A. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

Group B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

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

1.6 CLIMATE

The Springfield area has a temperate climate with distinct seasonal variations in temperature and precipitation. The average temperature, precipitation, evaporation, and relative humidity is 55.9°F, 43.2 inches, 42 inches, and 72.5 percent, respectively. Table 1-2, Climatological Data, contains the average monthly temperatures, precipitation and evaporation.

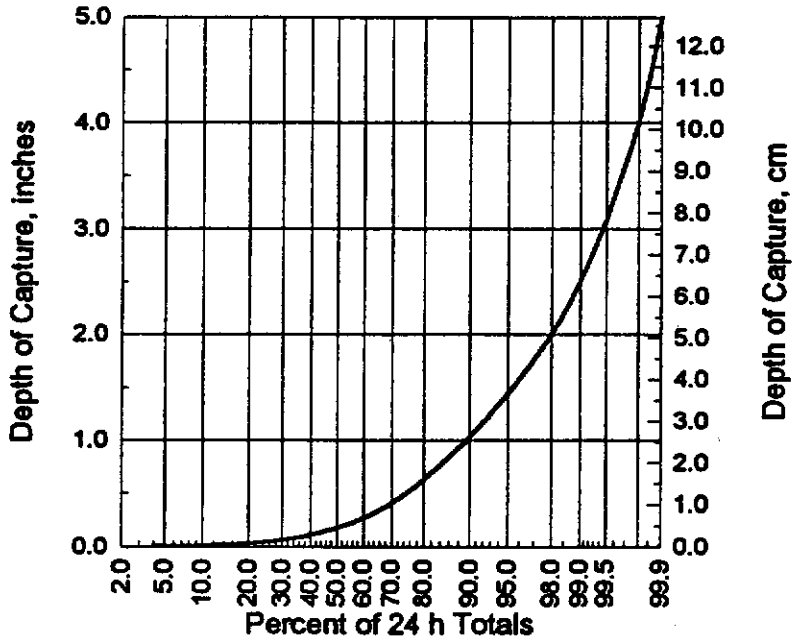
Water quality issues require different rainfall data than the design of flood control structures. The control of runoff from frequent rainfall is more important than the control of statistically infrequent events. The relationship between the depth of rainfall and percent of 24-hour totals for the Springfield region is shown in Figure 1-2. For example, for the period of record, a water quality control measure that dealt effectively with the first one inch of rainfall will take care of 90 percent of the days in which measurable precipitation occurred.

[2]As of January 1995, the Soil Conservation Service is known as the Natural Resources Conservation Service.

TABLE 1-2
CLIMATOLOGICAL DATA

Month	Average temperature (degrees F)	Average precipitation (inches)	Average evaporation (inches)
January	32.6	1.66	0.3
February	36.6	2.07	0.5
March	44.2	3.72	2.8 (7.1)
April	56.0	4.38	4.3
May	65.0	4.41	5.0
June	73.5	5.17	6.0
July	77.7	3.59	6.8
August	76.7	3.35	6.2
September	69.1	4.64	4.0
October	58.3	3.75	3.0
November	45.0	3.45	2.7
December	35.9	2.98	0.4

FIGURE 1-2
DEPTH OF PRECIPITATION VERSUS PERCENT OF 24-HOUR TOTALS



National Weather Service, Hourly Precipitation, Springfield, Missouri.
Period of record January, 1958 - October, 1988.

1.7 LAND USE

32% in City

Approximately 9 square miles of the recharge area are within the city limits of Springfield. With the exception of the railroad corridor along the south watershed boundary and the I-44 corridor west of Glenstone Avenue, the primary land use is residential (City of Springfield 1994). The railroad corridor is primarily general and heavy manufacturing and the major intersections with I-44 are general retail districts. This area is the most heavily developed. It is drained by Pea Ridge Creek. Pea Ridge Creek has not been shown to be directly connected to Fulbright Spring. Some diffuse recharge may occur. This may account for the relatively minor degradation of spring water quality even with the high degree of urbanization.

The area east of Glenstone and south of I-44 is primarily used for general and heavy manufacturing. There are still several large tracts of undeveloped land in this part of the recharge area with general or heavy manufacturing zoning. Several trucking operations are located at the I-44 and U.S. Highway 65 intersection. The new Partnership Industrial Park is in the extreme southeastern corner of the recharge area. The surface drainage from this area goes to the Valley Water Mill reservoir, providing a direct path to Fulbright Spring.

Land use outside the city limits is primarily agricultural and residential. The corridor between the South Dry Sac River and I-44 is most heavily developed as residential property. North of the South Dry Sac River development is significantly less dense and the predominant land use is agricultural.

The approximate land use distribution of developed land in the recharge area is shown in Table 1-3.

TABLE 1-3
CURRENT (1995) LAND USE

Land Use	Percent of Developed Land
Residential	30
Commercial	9
Industrial	13
Transportation	40
Community	2
Parks	6

Table 1-4 shows the estimates of acreage by use for new development in the Fulbright Spring recharge area over the next 20 years. Drawing 4 provides a graphical representation of the watershed and the land use estimates. The largest tracts of undeveloped land are in Greene County outside the City of Springfield. City and County planning departments staff indicate that with the recent completion of the South Dry Sac Trunk Sewer, development pressure is expected to increase significantly. With increased development in the recharge area that is directly connected to Fulbright Spring, there is an increased potential for further degradation of spring water quality by virtue of stormwater runoff characteristics during and after construction and due to increased spill potential.

TABLE 1-4
ESTIMATED LAND USE CHANGES FOR THE FULBRIGHT SPRING RECHARGE AREA OVER THE NEXT 20 YEARS*

Category	Acres	Estimated Dwelling Unit Totals
Large lot residential (3-acre lots)	1,630±	543
Single family residential (2.5 DUA**)	2,027	5,067
Medium density residential (10 DUA)	160	1,600
SUB-TOTAL RESIDENTIAL	**3,800**	**7,210**
Non-residential (unspecified)	1,150	
Commercial	100	
Industrial	100	
Industrial/Commercial	70	
SUB-TOTAL NON-RESIDENTIAL	**1,400**	
TOTAL ACREAGE	**5,237**	

*These figures represent *additions* to the current land use totals
**DUA: Dwelling units per acre

1.8 GEOLOGY AND AQUIFER CHARACTERISTICS

Other physical aspects of interest for the Fulbright Spring recharge area include; (1) geology, (2) surface and groundwater hydrology, (3) aquifer characteristics, and (4) Fulbright Spring characteristics.

Detailed discussions of these subjects are presented in the following chapters.

CHAPTER 2
GEOLOGY AND HYDROLOGY

2.1 INTRODUCTION

This chapter was prepared to summarize the basin survey completed in the process of identifying sensitive environmental features (SEFs) in the Fulbright Spring watershed and to identify data gaps in the presently available set of information. The primary contributors to this chapter were Mr. Fred Palmerton, P.E., Dr. Ken Thomson, and Dr. Edwin Herricks. Mr. Palmerton has extensive geologic and geotechnical engineering experience in the Fulbright Spring recharge area. Dr. Thomson is on the faculty at Southwest Missouri State University and has considerable dye tracing experience in the Fulbright Spring recharge area. Dr. Herricks is on the faculty at the University of Illinois and is recognized as one of the top "wet weather" receiving water impacts specialists in the United States.

2.2 DATA SOURCES

Information was gathered from a variety of sources for the identification and ranking of SEFs. Aerial photography from 1990 was provided by the City of Springfield Department of Community Development. Additional sources of information included Geologic Map of Greene County prepared by Kenneth C. Thomson, a *Geologic Study of Proposed Sewer Route Along South Dry Sac River, Greene County, Missouri* prepared by Kenneth C. Thomson, USGS 7½ minute series quadrangle maps, *Structural Features of Missouri* prepared by Mary H. McCracken, *Identification of Numerous Small Karst Features* provided by Kenneth C. Thomson, *Geology of Greene County, Missouri* prepared by Kenneth C. Thomson, and available dye trace information obtained from the Watershed Committee of the Ozarks. Numerous additional sources of information including planning, zoning, ownership, and projected land use information were readily available, but not included as this was intended to be an initial reconnaissance level assessment of SEFs. The sources are noted however, to assist in the extension of this study into the next level. This may not be a complete list of available data. Reviewers of this report are encouraged to provide additional sources of data that they may have knowledge of or access to.

2.3 GEOLOGIC AND HYDROLOGIC SUMMARY

2.3.1 REGIONAL SETTING

The Fulbright Spring watershed is located in central Greene County on the western side of the Ozark uplift. The general area is characterized by rugged to rolling terrain, meandering streams and karst topography. Typically, alluvium and loess soils overlay units of crystalline limestone (Warsaw and Burlington-Keokuk Formations). The limestone is highly susceptible to solution weathering resulting in the rapid movement of groundwater and the formation of sinkholes, caves and other karst features. Underlying the Burlington-Keokuk Formation is the Elsey Formation, the Pierson Formation, and the Northview Shale. The shale layer ranges in thickness from 20 to 60 feet in the study area. It functions as an aquitard and separates the groundwater into two distinct regions, an upper or minor aquifer, and a lower or major aquifer. There are a number of faults in the study area (Plate 2, Area Geology) along with a significant number of residential wells that may provide a connection between the upper and lower aquifers. Chemical analysis of the water from both aquifers shows a significant connectivity between the two (Missouri Department of Geology and Land Survey 1978). A more detailed description of the area geology can be found in *Geology of Greene County, Missouri* (Thomson 1986).

2.3.2 STRATIGRAPHY

2.3.2.1 Quaternary System

Residuum. Residuum soils are present throughout most of the recharge area. These overburden soils are usually composed of red clay and chert and are developed from physical and chemical weathering of the parent rock. Numerous chert fragments are common within the residual soils due to the relatively high chert content contained in the limestones and dolomites. The thickness of these residual soils can vary from 0 to in excess of 20 feet.

Alluvium. Alluvial deposits are present in stream valleys. This unit consists primarily of sand, silt and gravel. These materials have been transported and deposited in valley floors by running water. These gravels are usually composed of chert or limestone with lesser amounts of silt and sand. Alluvial deposits vary in thickness from zero to in excess of 30 feet.

High Terrace Gravels. Thomson (1986) describes the lithology of high terrace gravels as materials containing "granule to cobble dimensions" and are fairly highly polished.

2.3.2.2 Mississippian System - Osagean Series

Burlington-Keokuk Formation. The Burlington-Keokuk Formation underlies the majority of the recharge area. The Burlington-Keokuk Formation has been surficially eroded since it is the exposed surface formation. Its true thickness, therefore, is quite variable and ranges from zero to 130 feet. This unit characteristically consists of coarse-grained gray limestone which is near pure calcium carbonate. Isolated chert nodules and discontinuous chert layers are present throughout the formation. The upper surface of this limestone unit is generally irregular due to the effects of differential vertical weathering and solution activity. Limestone pinnacles, some of which are 10 to 15 feet high, are common in the general area. The limestone unit is generally medium-bedded and coarsely crystalline. This limestone unit is highly susceptible to solution activity and karst features are very common throughout this formation.

Elsey Formation. The Elsey Formation is a dense gray cherty limestone, containing few fossils. It varies from 50 to 55 feet thick in the study area. The limestone is generally gray and finely crystalline. The chert content of the formation ranges from 25 to 50 percent. Thomson (1986) describes the cherts of the Elsey Formation as varying,

> ". . . in form from nodules to long lenses or beds. Both forms can be found in a single outcrop. The chert may have either smooth, gently-rounded surfaces or it may be irregular or rough. The chert nodules and lenses range from 6 to 12 inches thick and are highly variable. The chert is mottled gray and white on the interior and very white to light gray on the surface. Elsey cherts break down easily to physical weathering processes and in natural exposures they shatter into a rubble. Commonly the cherts make up the surface expression of the rock unit. The chert breaks up very easily, but does not break down itself. The result is a thick residuum of chert and clay with the limestone having been removed by solution."

Pierson Formation. Thomson (1986) describes the lithology of the Pierson Formation with three lithologic units.

> "The Pierson Formation consists of three lithologic units of nearly equal thickness. The lower Pierson is a massive, brown, earthy and silty, tough dolomite or dolomitic limestone. The middle Pierson is a medium-bedded brown to light brown dolomite or dolomitic limestone, containing layers of lenticular gray chert. The upper Pierson is a medium- to thin-bedded fossiliferous gray limestone which is light brown where the rock is slightly dolomitic."

The formation varies from 30 to 38 feet thick in the study area.

2.3.2.3 Mississippian System - Kinderhookian Series

Northview Formation. The Northview Formation consists of both siltstone and shale. The upper part of the unit is primarily siltstone with interbedded shales. The lower part of the unit is primarily shale with lesser amounts of siltstone. Thomson (1986) describes the unit as follows:

> "The siltstones in the formation are generally light brown to brown weathering to light brown on fresh fracture. In some areas it is light gray on fresh fracture. Some areas are even dark brown to reddish brown. The vermicular siltstone is so called because of the wormhole-like perforations which can be seen in many of the outcrops. This is the worm rock or field stones which are built into many houses in the Springfield area . . . The shales in the unit are from olive green to gray or gray blue and weather to form gray, clayey soils."

The thickness of the Northview in the study area is from 30 to 35 feet.

Compton Formation. The Compton Formation is a fine to medium-grained crystalline limestone containing small green shale partings. Crinoid columnals and pyrite-filled vugs are common throughout the formation. The Compton Formation is 10 to 15 feet thick in the study area.

2.3.2.4 Ordovician System - Canadian Series

Cotter Formation. The Cotter Formation consists of a medium to fine-grained cherty dolomite with occasional lenses of sandstone. The unit is usually light brown to gray and generally fine-grained. The upper surface of this dolomite unit is an unconformity and as such is an erosional surface. The thickness of the unit ranges from 50 to 200 feet in Greene County.

2.3.3 STRUCTURAL GEOLOGY

Brown Fault. The Brown Fault is an east/west trending fault located in the eastern part of the recharge area. This fault is described as a normal fault with the down thrown side on the north side. The indicated throw of the fault is believed to be from to 70 to 170 feet. The fault has been mapped through Sections 1, 2, 3, 4, and 5, Township 29 N, Range 21 W. The fault crosses U.S. Highway 65 approximately ½ mile north of I-44.

Valley Mills Horst. The Valley Mills Horst consist of two east/west trending faults located in the northern portion of Sections 1, 2, 3, 4, and 5, Township 29 N, Range 21 W. The faults terminate just west of Valley Water Mills Reservoir.

Strafford Fault. The Strafford Fault extends north and east from the northern Valley Mills Fault. This fault crosses the South Dry Sac River approximately 1¼ mile northwest of the intersection of I-44 and U.S. Highway 65. The normal fault is downthrown on the west side with a displacement of from 50 to 80 feet.

Fulbright Fault. The Fulbright Fault is located in the western portion of the recharge area. It extends from west of Highway 13 to a point in the eastern portion of Section 31, Township 30 N, Range 22 W. The fault intersects the South Dry Sac River approximately 2 miles northeast of Fulbright Spring. This fault is also described as a normal fault with the north side being displaced upwards from 180 to 210 feet.

Ritter Fault. This fault extends from west of Fulbright Spring westward outside the topographic recharge area. The north side of this fault is down thrown with approximately 80 feet of displacement.

Joints and Photolineaments. Numerous joints and fractures were mapped and described by Thomson (1986). Most of these linear features trend either northeast or northwest. These features are likely the result of previous uplift and subsequent faulting in the immediate site area.

2.3.4 KARST FEATURES

Karst landforms developed mainly from solutional processes acting on the Burlington-Keokuk Limestone are prevalent in the study area. This type of topography is referred to as karst. The landforms include cutters and pinnacles, sinkholes, caves, springs, and natural arches found throughout the recharge area.

Solution processes acting below the soil cover on the limestone create cutters and pinnacles which make the bedrock/soil interface highly irregular and the depth to bedrock quite variable. Larger solutional areas create sinkholes which can be either solutional or collapse features. These bowl- or basin-shaped depressions have a direct connection with the shallow groundwater system and should be protected in the same manner that rivers, streams, and lakes are protected. Collapsed sinkholes generally have larger openings or "eyes" which can make the connection even easier

and quicker. The sinkhole features range from a few feet to in excess of several hundred feet in diameter. They also range from a few feet to as much as 35 or 40 feet deep.

Caves and springs are also common in the study area. Most of the caves are found in the western part of the study area, but there are a few on the east side as well. Most of the caves are small, with the exception of the Fulbright Spring Cave, which has been surveyed for approximately a half mile to the northeast of its opening and Hillsink Cave (Devils Slide Cave), just to the northeast of Fulbright Spring which is also quite large. Natural arches are the remnants of caves and several are found just to the north of Fulbright Spring.

2.3.5 HYDROLOGIC MASS BALANCE

There are no gaging stations on any of the surface streams or recording rain gages in the Fulbright Spring recharge area. The following mass balance computations are based on the National Weather Service rainfall data at the Springfield Regional Airport, City Utilities of Springfield (CU) spring flow records, and Missouri Department of Natural Resources average annual runoff estimates for Missouri.

The computations are not rigorous and do not show a quantitative relationship between the surface runoff and springflow. The mass balance presented does provide some additional insight into the spring recharge mechanisms, however.

Over the 41-month period of record the average annual precipitation was 48.7 inches. Over this same period the spring had an average flow of 7.8 MGD. Runoff for this area averages 28 percent of the average annual rainfall (Missouri Department of Natural Resources 1984). Computations are provided only for the surface drainage upstream of the swallow hole just downstream of Valley Water Mill Reservoir.

Precipitation	48.7 inches/year
Runoff	13.5 inches/year
Abstractions	Precipitation - Runoff = 48.7 in/yr - 13.5 in/yr = 35.2 inches/year
Area	15.39 mi^2
Spring	7.8 million gallons/day = **3.808×10^8 ft^3/yr**
Runoff	(13.5 in/yr) x (15.39 mi^2) = **4.827×10^8 ft^3/yr**

The mass balance computations indicate the springflow closely matches the total runoff from the watershed upstream of the swallow hole. The swallow hole does not capture all of the runoff in the stream from a storm event. Therefore, streamflow cannot account for the springflow in its entirety. This implies significant recharge is occurring from sources other than the swallow hole. Additional stream gaging will be required to more accurately determine the amount of recharge from surface runoff.

2.3.6 SUMMARY

The hydrology of the Fulbright Spring recharge area is very complicated. The following summary is intended to highlight what is known about the hydrologic conditions in the recharge area and their relationship to the existing geologic conditions.

1. The upper end of the South Dry Sac River has perennial flow prior to crossing U.S. Highway 65. Surface flow in this area is on top of the Northview Formation and no water loss is expected. As the stream flows across the Strafford Fault, some subsurface loss into the Elsey Formation probably occurs. This subsurface capturing may contribute to the recharge of springs located directly southeast of Valley Water Mill.

2. Surface flow of the South Dry Sac River below Valley Water Mills is largely captured in a swallow hole located directly west and downstream of the reservoir. Dye trace results demonstrate the direct connection of the swallow hole to Fulbright Spring.

3. Jarrett and Sander Springs, located directly southeast of Valley Water Mills, are both located in close proximity to the Valley Mills Horst. Surface flow crossing the Valley Mills Horst in Sections 2, 4, and 5, Township 29 N, Range 21 W, may be diverted into the groundwater system and contribute to the recharge of these springs.

4. Surface flow passing beyond the swallow hole located near Valley Water Mills is captured by numerous small sinkholes in the stream valley as characterized by dye trace studies. In addition, substantial water loss into the Elsey Formation in this area below the swallow hole has been dye traced directly to Fulbright Spring.

5. Dye trace results indicate that Sander Spring is partially recharged from apparent losing portions of tributaries located in Sections 4 and 5, Township 29 N, Range 21 W.

6. A large sinkhole located in the central portion of Section 6, Township 29 N, Range 21 W, has been dye traced to both Sander Spring and Fulbright Spring.

7. The Pea Ridge Creek tributary is known to be a losing stream. Waters resurface from this tributary near Fulbright Spring within the creek bed.

8. Dye injected in a sinkhole located in the southeast quarter of Section 5, Township 29 N, Range 22 W, was detected in Fulbright Spring. This sinkhole feature is outside the topographic boundary of the recharge area.

2.4 DATA GAPS

1. It is unknown how much subsurface movement of water from outside the topographic boundary of the recharge area actually contributes to Fulbright Spring. A single dye trace was found which indicates that the spring is indeed recharged from areas located outside its topographic boundary.

2. The amount of surface waters captured by sinkhole features and losing segments of tributaries which do not contribute to the Fulbright Spring system is unknown.

3. Dye trace results indicate that the Valley Water Mills system is directly connected to Fulbright Spring. The precise recharge area of springs contributing to Valley Water Mills has not been determined. It is likely that these springs are fed through numerous solution channels and may be associated with faulting in the area.

4. The connection between Fulbright Fault and the South Dry Sac River should be investigated to determine whether or not this fault contributes to Fulbright Spring.

5. Numerous sinkhole features are located within one mile of Fulbright Spring. The precise connection between these features is unknown.

2.5 CONCLUSIONS AND RECOMMENDATIONS REGARDING GEOLOGY AND HYDROLOGY

Within the framework of the Phase I study, a number of source/features/transportation path combinations have been identified that potentially could have an effect on the water quality issues

at Fulbright Spring. This list was compiled based on information available on the 1990 aerial photographs of the South Dry Sac River basin and from information readily available and documented as described in previous sections of this report. Studies indicating the movement of groundwater into and out of the Fulbright Spring topographic watershed do not define under what hydrologic conditions the movements occur. Therefore, recommendations are made to obtain additional information within the basin which include:

1. Instrument the basin with three to four recording streamflow gauges, one of which should be located immediately downstream from Valley Water Mill and a second immediately upstream from the swallow hole. The location of the other two streamflow gauges should be determined during the Phase II study. Also, the installation of three recording rainfall gauges is recommended. One should be in the Partnership Industrial Center Complex, one near the Pleasant View School, and the third in the vicinity of Fulbright Spring. Analysis of data from these recording stations, coupled with flow rates from Fulbright Spring, will enable a better estimation regarding the relationship of rainfall, streamflow, and springflow and will allow refinement of the hydrological mass balance; i.e., the percentage of mass rainfall which becomes runoff, evapotranspiration, and groundwater. This information, coupled with additional dye tracings, may also provide more definitive information on the amount of water entering and leaving the watershed, and under what hydrologic conditions those movements occur.

2. Local geologists/hydrologists should perform additional dye traces. Coordinate the dye trace operations with hydrologic events that allow the extrapolation of the dye trace results to rainfall/streamflow/springflow combinations.

3. Continue the record search beyond the information contained in this study to identify and plot known Underground Storage Tanks (USTs) and to update the source base from the 1990 aerial photographs to more recent photographs or spend considerable time in the field spot checking the watershed for developments that are more recent than 1990. For instance, the Wal-Mart Supercenter Site in the southwest quadrant of Kansas and I-44 was not included in this study.

4. Tweak the rating scale for transport paths in the rating system described in Chapter 5. Also evaluate any new source/features/transport path combinations found.

5. Identify a list of contaminants which will cause specific degradation of water quality of Fulbright Spring, then field check sources within the watershed to determine the quantity of contaminants used or contained at the various sources and the probability of release. This recommendation is made with the knowledge that even the best management practices will not treat all potential contaminants, but will allow re-evaluation of BMP recommendations.

CHAPTER 3
FULBRIGHT SPRING WATER QUALITY

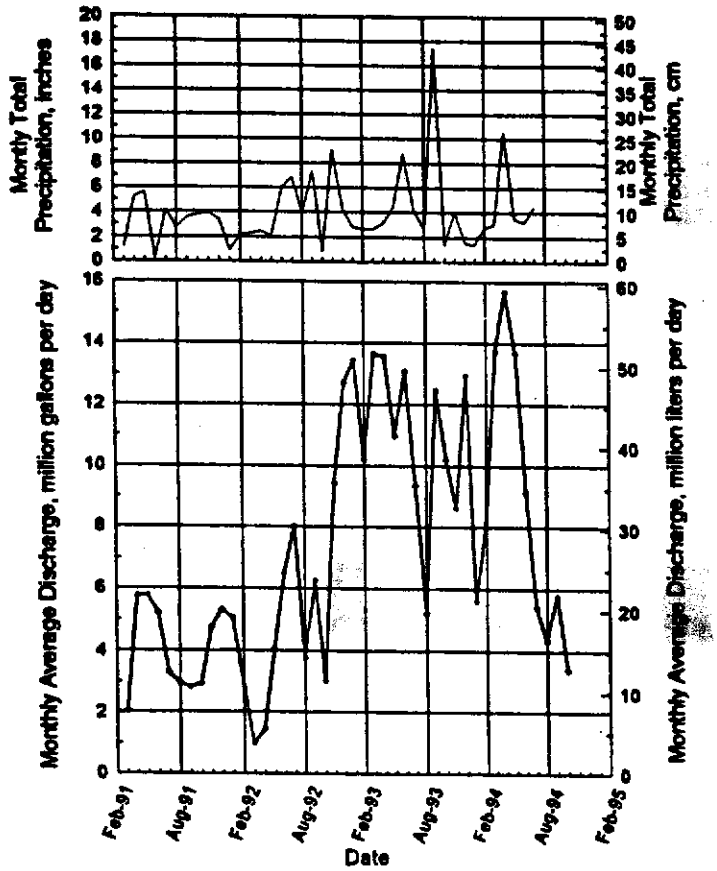
3.1 SPRING CHARACTERISTICS

As discussed previously, the Northview shale layer functions as an aquitard and separates the groundwater into two distinct regions, the upper or minor aquifer, and the lower or major aquifer. Fulbright Spring is located in the upper aquifer. It discharges from 2 to 14 million gallons per day (MGD). Wells completed in the lower aquifer are at depths of 1,200 to 1,700 feet. A downward hydraulic gradient exists between the upper and lower aquifers due to pumpage, such that the upper aquifer significantly recharges the lower. There are a number of faults in the study area and a significant number of residential wells that may provide a connection between the upper and lower aquifers. Chemical analysis of the water from both aquifers shows a significant connectivity between the two.

The recharge area boundary corresponds to the surface drainage areas of several different watersheds (see Drawing 1). Thus, a particular groundwater path may cross surface drainage divides. Dye traces have shown a direct connectivity from the swallow hole on the South Dry Sac River to Fulbright Spring with travel times as short as three hours over a distance of 2.5 miles (4.0 km). The connection between the upper South Dry Sac River and Fulbright Spring has been recognized since at least the 1890s. When the Valley Water Mill Reservoir was first filled, flow at Fulbright Spring was depleted almost entirely. A pipe was installed to redirect flow from the reservoir to the swallow hole on the South Dry Sac River. While it is known that the water captured by the swallow hole just downstream of Valley Water Mill provides part of the springflow, inspection of precipitation and springflow records shows that it is likely that most of the springflow comes from other, possibly diffuse or discreet sources. Losing stream sections are common throughout the area, with the South Dry Sac River the most significant losing stream. Further investigation, including streamflow, precipitation monitoring, and dye tracing is required to more accurately determine sources of flow.

Fulbright Spring responds quickly to precipitation. The average monthly flows for March 1991 through October 1994 and corresponding monthly precipitation are shown in Figure 3-1.

FIGURE 3-1
FULBRIGHT SPRING DISCHARGE AND PRECIPITATION TOTALS



Period of record March 21, 1991 - October 26, 1994
City Utilities Central Laboratory
Spring Report, City Utilities, Springfield, Missouri 1994

Precipitation enters the groundwater system through losing streams, sinkholes, faults, and fractures. This direct connectivity makes the spring susceptible to contamination from surface runoff. CU spring quality reports indicate an increase in turbidity and bacterial contamination immediately after a rainfall event that produces runoff. Additionally, the variation from maximum to minimum measurements for parameters such as total bacteria, coliforms, and turbidity tend to be several orders of magnitude. This is typical of a "flashy" hydrology that responds quickly and with a minimum of natural buffering.

3.2 WATER QUALITY DATA

Although an extensive data set exists on the general quality of Fulbright Spring water, only limited data are available to relate specific sources or environmental conditions (such as wet-weather flows) to water quality. A review of water quality summaries from 1985 to the present shows a correlation with wet weather events, but confirmation of that relationship must await more detailed analysis that will connect specific sampling dates with rainfall.

The record also contains some data on trace organics and toxic substances. The available data indicate there have been no detectable quantities of dioxins, pesticides, semi-volatile and volatile organic compounds (VOCs) other than a single detection of bis (2-Ethylhexyl) phthalate. These data are shown in Appendix 8. There are not enough wet weather data for organic compounds to provide any definitive statements about the possible presence of these compounds during and immediately after rainfall events.

In October 1994, the CU Central Laboratory performed screening tests in areas around lower Pearson Creek for VOCs. Although this watershed is separate and distinct from the Fulbright Spring recharge area, the results are relevant as an indicator of how urbanization may affect ground and surface water quality. Levels of TCE (3.5 ppb) were found in the creek as well as 11.5 ppb in Jones Spring. Also found in Jones Spring were detectable levels of bromodichloromethane, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, 1,1,1-trichlorethane, and tetrachloroethylene. These compounds are typical of industrial processes that use such solvents (metal-finishing, metal cutting, pharmaceutical manufacturers, and others), although they do not imply one specific source. These data are also provided in Appendix 8.

The biological data set that is available for interpretation of water quality is limited. There are good data on Valley Water Mill plankton and general trophic condition, as well as watershed surveys for McDaniel/Fellows watershed, the Little Sac River, and the Upper James River, but these studies are not specifically connected to Fulbright Spring stormwater quality, nor do they address specific issues associated with streams directly contributing to Fulbright Spring.

3.3 DRINKING WATER TREATMENT

The most important beneficial use of Fulbright Spring water is as drinking water for the Springfield area. Whether the quality of the water is adequate for this use is largely a

technological question; i.e., is the water of such a quality that it can be made suitable for drinking water using available treatment processes?

In the case of Fulbright Spring, the existing treatment facility consists of a typical alum coagulation/flocculation/filtration system, supplemented by the addition of chlorine and carbon treatment to disinfect and remove tastes and odors. This system is used to reduce levels of conventional contaminants such as suspended solids and bacteria to levels required by federal and state laws. High loadings of suspended solids may result in excessive sludge production and frequent backwashing of the filters. Nitrates and organic compounds are not effectively removed by this type of facility. Carbon adsorption, ion exchange, UV photolyzation, or other more sophisticated processes would be required to significantly reduce concentrations of these contaminants. Such processes are expensive in terms of both the capital and operations and management costs. As a result, it is highly desirable to minimize the risk of introducing these contaminants into the raw water supply (and thereby forcing the upgrading of the present treatment process). This is the basic goal of the project sponsors, and especially CU. This subject is discussed more fully in Chapter 6.

CHAPTER 4
ALTERNATIVE APPROACHES FOR ESTABLISHING PROTECTION CRITERIA

As part of Phase I of the *Fulbright Spring Protection Study*, WWE has analyzed various methods for the control of water quality within the Fulbright Spring watershed. Before these methods can be utilized however, the criteria that will be applied to determine their success or failure must be defined. Once these criteria are established, there will be clear reasoning and justification available for the development of specific laws and regulations for water quality protection. This is essential in obtaining the acceptance of the protection plan by the public and commercial interests.

The purpose of this chapter is to enumerate and examine the possible approaches to development of protection criteria for the Fulbright Spring recharge area. By understanding the underlying philosophy and advantages and disadvantages of each approach, the study sponsors will be able to make well-informed decisions as to the selection of protection criteria.

4.1 OVERVIEW OF WATER QUALITY CONTROL PHILOSOPHY

4.1.1 INTRODUCTION

In order to develop a working basis for the establishment of water quality policy for the Fulbright Spring recharge area, it is valuable to review the various approaches that have been proposed, utilized, and sometimes abandoned. A brief historical overview sheds light on the nature of those philosophies and the reasons for their success or failure. From this, it should be possible to determine what approaches are most applicable to Springfield and the Fulbright Spring drainage basin.

4.1.2 HISTORY

What is generally regarded as the first piece of water pollution control legislation in this country is the Rivers and Harbors Act of 1899. This was an excellent example of the "beneficial use" oriented philosophy to water quality control. This legislation was designed only to regulate potential obstructions to navigation, but became the cornerstone and primary justification for the federal water pollution programs begun in the 1960s. Until the 1972 Clean Water Act, pollution

control emphasized the quality of the receiving waters, and not the discharges entering them. With the 1972 Act came three major aspects: (1) a goal of elimination of pollution discharges, (2) technology-based effluent limitations to support existing water quality standards, and (3) a federal "command-control" structure for water pollution policy. The NPDES was the part of the 1972 Act meant to monitor and control pollutant discharges, taking into account the beneficial use of the receiving waters and the discharge's impact on those waters. The terms "Best Practicable Technology" (BPT) and "Best Available Technology" (BAT) were used to describe the technology-forcing standards used to control discharges. In the 1977 Act, economics were taken into consideration in developing Best Conventional Technology (BCT) standards. Additional water quality standards were also introduced.

An important aspect to the 1987 Clean Water Act is Section 303(e). Here, the use of a classification system for river basins is the basis for water quality management. If BPTs can be used to meet stream standards, then the segment is classified as an "effluent limitation" segment. If BPTs do not improve stream quality sufficiently to meet the standards, the segment is classified as "water quality limited." Thus, a combination of technology-based controls, stream standards, and water quality management tools are used to achieve the desired goals. Also in the 1987 Act is the concept of "antidegradation" (see 40 CFR Sec. 35.131.12). Antidegradation requires not only that beneficial uses be maintained, but that streams with water quality that exceed the standards may not be degraded in quality, subject to economic and social considerations. Thus, this is a combination of a strict antidegradation concept with maintaining beneficial use.

During all of this emphasis on surface water, no standards for groundwater were developed. Typically, states have relied on drinking water maximum contaminant levels (MCLs) to set groundwater standards. In a General Accounting Office (GAO) memo on the use of drinking water standards for groundwater protection, it is noted:

> ". . . we found that the MCLs for 17 substances are less stringent than EPA and NAS aquatic life guidelines and therefore would not always protect aquatic life. . . A decision to apply EPA maximum contaminant levels as groundwater standards, without allowing for greater stringency when local conditions warrant it . . . could jeopardize sensitive species of aquatic life."

Additionally, the use of MCLs does not take beneficial uses into account. If an aquifer has an ambient water quality such that it is unfit for drinking water and would be costly to treat to the necessary quality, should MCLs be applied?

The second issue that is not thoroughly addressed in federal legislation is that of nonpoint source (NPS) pollution. Section 208 of the 1972 Act and Sections 319 and 405 of the 1987 Act are essentially voluntary compliance programs with little "teeth" to them. Structural BMPs are used as a NPS equivalent to BAT practices that the Clean Water Act used for abatement of point source discharges. Land use or nonstructural BMPs are management tools. There are, however, several difficulties in applying point source solutions to NPS problems:

1. The "command and control" approach simply does not work with NPS discharges. There is typically no single polluter and no pipe to monitor. BMPs usually have to be tailored to each individual watershed; there is no universal set of rules that can be applied as to what technologies or management tools will be successful.

2. Stating that a given structural BMP will increase water quality by a certain amount in a certain setting is much more difficult than point source management. Whereas the effectiveness of a variety of point source treatment options can be predicted and controlled with significant precision, the effectiveness of structural BMPs is limited to proper design and maintenance. There are limited data on these BMPs to precisely indicate their efficiency in any given situation.

3. Urban NPS discharges and their effects on receiving bodies tend to be very "flashy" due to storm runoff; impacts may be completely missed, even with frequent monitoring.

4. The image of a pipe discharging pollutants into a pristine stream is immediately recognizable by the public and the media as a critical problem that must be remedied (whether or not that is the reality of the situation). The amount, toxicity, and impact of runoff from a parking lot may be many times greater than the point discharge, but it is difficult or impossible for most to see as a serious problem in need of remedy. Additionally, it is that same public that is directly responsible for most of those NPS pollutants.

4.2 OPTIONS FOR WATER QUALITY STANDARDS

The issue to be addressed in this section is how to develop a set of criteria or standards by which the success of a NPS ground and surface water protection plan will be judged. Based on the previous discussion, the following options are offered:

4.2.1 STATUS QUO (ESTABLISH NO NEW SURFACE OR GROUNDWATER QUALITY STANDARDS)

Clearly, the status quo offers many advantages: no new regulations are required, minimal resistance from commercial interests, and low initial cost. Since water quality problems are currently of a limited scope in the watershed, this is a viable option. Note in the discussion above that federal water quality law has been largely reactionary in nature, as opposed to the proactive approach suggested by this Phase I study. There is certainly economic benefit and legal precedence for this approach.

In fact, the disadvantages to this approach may not always be as clear. Note the difficulty mentioned previously in getting public and commercial support for NPS pollution prevention as opposed to point source. Nonetheless, disadvantages exist. If it is later determined that water quality controls must be utilized (as they most likely will), retrofitting of structural BMPs will be expensive and new land use practices will not be as effective due to the "grandfathering" of existing sites. Furthermore, urban runoff typically contains more exotic contaminants than runoff from undeveloped watersheds. These contaminants may include metals, fuels, solvents, oils, grease, and other organics, as well as the same common nutrients, dissolved and suspended solids, etc. Many of these have high toxicities at very low concentrations, and once in a groundwater system they can be very difficult and expensive to remove. Conventional water treatment is not effective at removing many of the more exotic pollutants, again requiring expensive treatment facilities for drinking water supply. Thus, the long-term costs of maintaining the status quo can be very expensive.

One must also consider the interests and demands of the public. It is unlikely that the citizens of Springfield will support a policy that allows degradation of their water supply, particularly with the kinds of pollutants that can be found in urban runoff. Also, there is often a stronger negative response to contamination by organic compounds as opposed to more conventional pollutants. This is an issue best understood by managers from CU and local government, as they are the most directly impacted by public opinion.

The status quo approach would probably be described as a reactive rather than a proactive approach to water quality. Urbanization of the watershed *will* cause increased runoff, and the pollutants found in that runoff will be of a nature and concentration not previously seen in this area. In the long term, a reactive approach will be many times more expensive than a proactive approach, since instituting small-scale BMPs (structural and nonstructural) for pollution control

has been shown to be less expensive than retrofitting large, regional BMPs. Finally, it should be recognized that the study sponsors have not indicated any desire to approach water quality problems in any other manner than a proactive one.

4.2.2 REQUIRE BMPs IN THE RECHARGE AREA BUT REFRAIN FROM SURFACE AND/OR GROUNDWATER QUALITY STANDARDS

The definition of "Best Management Practices" is extracted from the August 19, 1987 national EPA guidance on NPS pollution controls and water quality standards (EPA 1987). Note also the parent definition of BMPs in 40 CFR 130.2(1) from which this simplified EPA guidance definition is drawn:

> Best Management Practices (BMPs) are methods, measures or practices to prevent or reduce water pollution, including but not limited to, structural and nonstructural controls, operation and maintenance procedures, other requirements and scheduling and distribution of activities. Usually, BMPs are applied as a system of practices rather than a single practice. BMPs are selected on the basis of site-specific conditions that reflect natural background conditions and political, social, economic, and technical feasibility.

BMPs are typically broken into two groups; structural and nonstructural. Structural BMPs involve physical installations or designs, such as detention ponds, sand filters, vegetated swales, wetlands, etc. These can vary from small, on-site BMPs and landscaping designs to large detention ponds that collect runoff from a large number of individual sites. Nonstructural BMPs may include impervious area limitations, public education, overlay zones for land-use management, etc. Land-use management and other nonstructural BMPs can be very effective in preventing direct runoff to streams, sinkholes, and other sinks where direct contamination of surface and groundwater may occur. The key is that these BMPs must have a solid basis for enactment in order to survive the tests of public acceptance and possible legal challenge.

The use of BMPs as the basis for stormwater quality management programs without regulatory linkage to water quality standards is typical of most programs throughout the country. For example, the stormwater programs in Florida, Maryland, and Delaware have all set a minimum treatment level for structural BMPs equal to the removal of 80 percent of the average annual loading of total suspended solids. In these cases, the use of previous studies of the hydrology and contaminant transport processes in the basin have been used as the regulatory basis for these criteria, rather than water quality standards. Essentially, it is the health of the receiving waters'

ecosystem and other beneficial uses of the waters that are of concern, whether water quality standards or performance standards are used. Performance standards, such as those just mentioned, are a much more direct, objective measurement of BMP effectiveness. They do not, however, directly measure the health of receiving waters, but only act as an indicator.

The key to the use of a BMP-based management program is the linkage of BMP use to the quality of receiving waters. Thus, even though the program does not specifically apply water quality standards, the monitoring of water quality is necessary to continually evaluate the effectiveness and need for BMPs, both structural and nonstructural. This provides both the legal and public support required for a stormwater management program to be successful.

4.2.3 ESTABLISH STORMWATER/RUNOFF EFFLUENT LIMITS AND MONITORING REQUIREMENTS IN THE RECHARGE AREA, BUT REFRAIN FROM SURFACE AND/OR GROUNDWATER QUALITY STANDARDS

This approach has the appeal of simulating the point source philosophy of end-of-pipe monitoring. The obvious question is "what pipe?" Unless flow is restricted and confined to very few points of discharge, where does one monitor to get a representative sample? If the sample is representative of a number of runoff sites, is the resulting information even useful? Note that this is different from the monitoring of individual BMPs in the manner described above, where specific points of discharge are in fact often available. Furthermore, when is the monitoring performed? Are the personnel available to immediately gather representative samples from every sample point when it rains? Or should the developers/land-owners/property managers be required to do the sampling? How can protocols be developed that will insure that representative samples will be provided? Certainly, some of these problems apply to the previous discussion as well, but a BMP-based program is different in that the effluent limits are design goals rather than regulatory limits.

4.2.4 ESTABLISH SURFACE AND/OR GROUNDWATER QUALITY STANDARDS IN THE RECHARGE AREA

This is another traditional approach to water pollution control that has the advantage of being objective and easily related to, or based upon, health standards. Several different approaches are available.

Narrative Standards. The narrative standard typically supplies either or both general criteria for water quality or an antidegradation standard such as that previously discussed. Missouri water quality law utilizes both (10 CSR 20-7.031[2] and [3]; see Appendix 3). General criteria include floating debris, color, odor, significant health hazard, etc. These are designed with surface water in mind, and the criteria typically do not apply well to groundwater. Antidegradation is deemed synonymous with maintaining beneficial use, but there is a distinction; antidegradation does not require there be any designated use. In a strict sense, antidegradation means no loss in quality. If existing quality does not meet the current beneficial use (note the coliform problem in Fulbright Spring), then antidegradation is not protecting beneficial use. If the beneficial use does not require the current ambient water quality, then antidegradation is again different from a policy that protects beneficial use. Antidegradation simply tries to prevent any decline in the quality of a water body.

Beneficial Use Standards. As discussed above, beneficial use standards identify all existing uses of the water and often all possible future uses. Water quality criteria needed to meet these uses are then set for the receiving waters and used as guidance for additional pollutant loading restrictions. This tends to be less limiting to development than antidegradation, and so may be more palatable to commercial interests. The hazard is that as EPA or the local public health agency revises standards or adds new pollutants to its standards, previously acceptable water quality may no longer be acceptable.

Maximum Contaminant Levels. As mentioned above, MCLs have often been used as the de facto standard for ambient water quality, particularly in groundwater. The philosophy is based on the traditional approach of supplying groundwater as drinking water with little or no treatment. That reality is not always valid, and many groundwaters (such as is the case in Fulbright Spring) are impacted by direct surface water infiltration. Still, this becomes a politically desirable option since the public's perception of groundwater is that it is always pure; and if it's not, man must be to blame. Everyone has experienced naturally turbid or anoxic surface water, but not groundwater. This is not to counter the fact that there are indeed many private wells throughout the country where no alternate water supply is easily available, and treatment is difficult and expensive.

In the case of Fulbright Spring, the use of MCLs is arguable, as the water is just barely definable as groundwater, and is better thought of as surface water. Is it realistic to apply such strict standards to water that receives so little natural filtration? At the same time, there are domestic water supply wells in Fulbright Spring that do not have treatment capacity. In the interest of

human health protection, MCLs would seem to be appropriate standards if these wells continue to be used.

Missouri Standards. The Missouri *Code of State Regulations* provides narrative and numerical water quality standards for surface and groundwater. Although surface water criteria are based on beneficial use, groundwater criteria are not. There are two exceptions to this statement: 10 CSR 20-7.031(5)(B) notes that Protection of Aquatic Life and Human Health Protection standards will apply when they are stricter than the groundwater standards and the groundwater contributes a significant part of the base flow to surface waters designated for aquatic life protection. Also, 10 CSR 20-7.031(5)(D) allows lowered standards in groundwater that does not meet the standards if the management authority can demonstrate that alternate criteria will not impair existing and potential uses.

Analysis of the Missouri groundwater standards shows that these are essentially identical to the MCLs, or standards for drinking water quality. The groundwater standard is defined as that which will yield potable water after treatment by public water treatment facilities, however, it is numerically as strict as the drinking water standards themselves (10 CSR 60-4.030 and 10 CSR 60-4.040). Thus, it is obviously assumed that only bacteria and turbidity removal will be required in the treatment process, as opposed to more sophisticated treatment technology.

One interesting aspect to the Missouri standards for groundwater is that these numerical criteria are specifically applied in any part of the aquifer, ". . . including the point at which the pollutant enters the aquifer." (10 CSR 20-7.031[5][C]). It is assumed that this was written given the conventional wisdom that filtering of water that infiltrates to groundwater occurs as the water moves through soil layers. In the Fulbright Spring recharge area, stormwater enters the groundwater virtually unfiltered through sinkholes. The net result is that strict interpretation of this regulation requires that stormwater runoff entering a sinkhole must meet drinking water standards. This may be an extreme interpretation, but it should be considered when referring to these regulations.

In conclusion, no single answer seems to be entirely adequate. For that matter, is the question itself well-defined? What is the purpose of developing water quality standards? Some options are:

1. Protect water quality for its own sake; water is a precious resource, and it can be argued that it must be kept as pure as possible. Beneficial uses, MCLs, and available BMP

technology are irrelevant. If this seems excessive, consider what philosophy is expressed by the Clean Water Act's "no discharge" and "fishable and swimmable" goals.

2. Protect water quality in order to maintain beneficial uses; but what does this mean? Fulbright Spring water is not drinking water until it passes through the treatment plant. It has historically been influenced by surface water such that its use as drinking water without treatment is risky at best (note presence of coliforms and suspended solids after storm events). In this case, the beneficial use of drinking water must likely be tempered with the fact that natural conditions in the Fulbright Spring recharge area will always require treatment before drinking. The goal may be to protect the water supply such that the existing treatment technology will continue to be adequate for providing a safe water supply.

3. Protect water quality for beneficial uses, but take economic and social development into account. For example, if development results in an increase in available funding, would it be reasonable to allow water quality degradation such that the treatment plant might require expensive refitting that would be paid for by development of the area? This may seem inappropriate, but is it possible to have an urban area that does not impact water quality? There is no technology by which a wastewater treatment plant will have no effect on a river's pH, nitrogen, phosphorous, temperature, and other water quality parameters. The argument against this approach comes from experience elsewhere that demonstrates how retrofitting existing water treatment facilities to treat for organic compounds and other typical urban pollutants is expensive in terms of both capital and operational costs.

4. What about other uses of the groundwater, such as recharge to fishable and swimmable waters or its effect on aquatic life in those waters? If protection of biota is a concern, these may require much more stringent standards such as those discussed in the Missouri groundwater standards and discussed previously.

Finally, as the basis for a stormwater management program, water quality standards are ambiguous indicators of the program's benefits. The quality of ground or surface water is the product of a great number of environmental factors, with stormwater quality mitigation as only one of these. Thus, there are a great number of confounding variables that must be considered when evaluating a stormwater management program on the basis of ambient water quality. In the case of the karst geology in the Fulbright Spring area, it may never be possible to meet water

quality standards, particularly in consideration of Missouri's application of the standards at the point of entry to groundwater. Thus, the strict use of water quality standards would seem to be a difficult approach for the Fulbright Spring area, at least initially.

4.3 COLORADO'S GROUNDWATER QUALITY STANDARDS

In order to bring this discussion to a more practical level, a summary is provided of some of the more salient points from the Colorado Code of Regulations (CCR) in which the Colorado Water Quality Control Commission (WQCC) promulgates standards for groundwater quality. The Colorado experience is discussed because of the long and careful consideration given to the issue by the WQCC, as well as WWE's direct involvement with these deliberations. Appendix 2 contains some of the comments included in the Code of Regulations (CFR) in which the WQCC explains its logic and rationale. Thus, this presents not only Colorado's approach, but fuel for further discussion, analysis, and decision-making.

- The purpose of the standards is stated as establishing ". . . a system of classifications (classes) for determining the appropriate degree of protection (standards) necessary *to maintain beneficial uses of groundwaters* . . ." Compare this to the objective stated in the Fulbright Spring Request for Proposal (RFP): ". . . make specific recommendations for policies, practices, and standards to be implemented *to prevent water quality degradation* . . . " As discussed above, in 40 CFR (35.131.12), the EPA's antidegradation policy is given as strictly protecting "existing instream uses," but allowing degradation of water quality for accommodation of "important economic or social development." Thus, EPA addresses these as two different issues.

- The WQCC used an Ad Hoc Groundwater Advisory Committee to get public input on the proposed standards.

- A classification system for groundwater use is used to determine what standards should be applied where. This is a logical extension of the philosophy expressed in the Statement of Purpose as discussed above, indicating that the WQCC did intend to have a beneficial use strategy for these standards.

- A combination of narrative standards, interim narrative standards, and numerical standards are used. Compared to the classification system, the narrative standards are strict anti-degradation standards which are to be applied statewide. The interim narrative standards

are defined as existing ambient water quality as of October 30, 1991, or Tables 1 through 4 from the numeric standards, whichever is less restrictive. The numeric standards apply to classified groundwater as well as the specified wellhead protection areas. These are primarily MCLs, although Table 3 standards are for agricultural protection (EPA/8/73/033). The Table A organic standards are also intended to be applied statewide, and have been changed to the generally more stringent "health-based standards for these constituents instead of standards equal to the MCLs, whenever health-based criteria are available."

For further examination of the comments and considerations made by the WQCC, excerpts from the relevant Colorado regulations are found in Appendix 2.

4.4 CONCLUSIONS

WWE hopes that this analysis will provide background information that will help CU and other project sponsors to identify potential goals for the recharge area. Further review of the alternatives is essential. The clear, thoughtful definition of the underlying goals of a pollution prevention program will result in fewer ambiguities as specific objectives are interpreted and applied.

A key point that is to be considered is that there does not appear to be one single approach to managing urban stormwater runoff that is entirely effective. Structural and nonstructural BMPs are the needed tools, but underlying goals and objectives must be clearly stated, possibly in numerical terms, in order to keep the program objective and accepted by developers and the public. The use of monitoring seems technically appropriate and effective, but costs can rapidly become a burden.

One conclusion that can immediately be drawn is that flexibility is a key to the success of a pollution control program. Any urban runoff management plan should include protocols by which the program is to be monitored, analyzed and refined. Monitoring can be used to determine the effectiveness of BMPs in order to assist in design refinement, rather than for a command/control procedure. Updating of BMPs will also be influenced by monitoring of the quality of receiving waters. Finally, flexibility must be maintained in the application of BMPs to specific sites.

It should also be noted that the adoption of the *Missouri Standards for Groundwater* as the basis for establishing a protection program for Fulbright Spring, offers an established and well-documented level of protection. In terms of community acceptance and legal defense, this is a conservative and reasonable approach. However, due to the direct effects of stormwater runoff on groundwater quality as previously discussed, these standards would be difficult and expensive to maintain. At this time, WWE recommends against enforcement of these standards on land use permitting decisions.

The study sponsors have asked WWE for our recommendation on which of the various water quality regulatory strategies should be adopted now. Careful consideration has been given to many technical and nontechnical factors, particularly comments made by the City, County, and Watershed Committee staff. Based on these, it is WWE's recommendation that, at least in the early stages of the watershed protection plan, the appropriate regulatory strategy to use is one that calls for mandatory implementation of various structural and nonstructural BMPs, but which goes no further. WWE believes that it is premature to adopt a regulatory program which would impose effluent limitations on stormwater treatment facilities or which would mandate compliance with the groundwater standards.

The recommended strategy for initiating the spring protection program emphasizes nonstructural controls, such as public/worker education, pollution prevention programs, minimizing directly connected impervious area, utilizing land development techniques which reduce the probability of pollutant discharge into the receiving water system, etc. These nonstructural controls are easily oriented toward the organic compounds which can result in greatly increased water treatment costs. Complementing these nonstructural efforts will be on-site structural BMPs that will be small and relatively inexpensive. To assure that the combination of nonstructural and structural BMPs is adequately protecting spring quality, there must be regular monitoring of spring water. From this information, adjustments will be made to the controls, if necessary, in response to the monitoring data.

Given an initial watershed protection strategy consisting of these three broad elements (nonstructural controls, structural controls, and monitoring, with adjustments to the control measures as necessary), the appropriate corresponding regulatory strategy is to emphasize that under most circumstances, new development projects in the Fulbright Spring recharge area will be required to implement structural and nonstructural controls, and that monitoring (of some sort) will be necessary where certain criteria for the proposed project must be met (size, runoff magnitude, nature of land use, etc.). There are two benefits to this approach: first, it places a more equal (and relatively inexpensive) burden in terms of water quality protection on the watershed's first developments as those several years from now; and second, it should reduce the need for more expensive regional and retrofitted structural BMPs later.

CHAPTER 5
SENSITIVE ENVIRONMENTAL FEATURES

5.1 INTRODUCTION

The scope of work for the *Fulbright Spring Protection Study* called for the completion of a preliminary basin survey to identify existing SEFs in the watershed. The WWE proposal called for preparation of a "white paper" that described and defined SEFs and defined what constitutes "areas with particular significance for water quality protection." In the WWE team interview with the study sponsors, the focus of this task was shifted slightly to add a study component that included identification of potential problem production areas, defined as specific sites which degrade surface water and groundwater quality. Problem production areas may include point and NPSs, originating from continuous discharges, episodic events, and spills. Finally, upon completion of these objectives, the Watershed Committee requested a discussion and analysis of the use of this rating procedure in the application to future land use decision-making as discussed in Section 5.3.

The section following this introduction provides a summary of the procedures selected for initial identification and ranking of SEFs. Appendix 1 provides an expanded description of the identification and ranking procedure, including a rationale for the methods selected and additional materials that support the methodology developed by WWE to identify and rank pollution sources and relate source potential to surface and groundwater quality degradation.

The initial identification and ranking of SEF features in the Fulbright Spring/South Dry Sac River Basin Project is a *reconnaissance-level assessment* intended to meet the specific needs of this project and provide a foundation for future tasks. This assessment has resulted in a list of well over 500 SEFs for the entire basin. As described in the following section, these have been hand-plotted on section maps and delivered under separate cover to the Watershed Committee. Although WWE has been asked to offer, if at all possible, a list of all possible immediate threats to Fulbright Spring's water quality, the Phase I level analysis does not permit definitive recommendations in this regard. Instead, it has been noted that any area near losing stream sections, particularly around the South Dry Sac River from the Valley Water Mill to "H" Highway, and any area immediately surrounding sinkholes should be considered as especially sensitive and in need of particular attention.

5.2 PROCEDURES SELECTED FOR INITIAL IDENTIFICATION AND RANKING OF SEFs

5.2.1 DEFINITION

As a starting point for the identification and prioritization of SEFs, it is important to define a "sensitive environmental feature." In the Fulbright Spring/South Dry Sac River basin, a SEF is any definable source, transport pathway, or landscape feature associated with environmentally damaging conditions. This definition recognizes that the presence of a feature, such as a swallow hole, will be of little consequence unless that feature contributes to environmental, or more specifically, water quality degradation. Sensitivity, as considered in this definition can vary and is based on the real, or estimated, potential for the production of environmental degradation. The breadth of this definition allowed WWE to combine "areas with significance for water quality protection" and "potential problem production areas" as elements of any SEF.

5.2.2 INITIAL IDENTIFICATION AND RANKING OF SENSITIVE ENVIRONMENTAL FEATURES

Initial SEF identification was first completed using maps and aerial photos. Each identified SEF was located on a basin base map (for larger areas an area was defined), numbered, and identified with a familiar location descriptor for use in the watershed Geographic Information System (GIS). Possible pollution sources were determined based on land use, existing monitoring data, or other data sources that provide information on the presence of contaminants (e.g., Superfund Amendments Reauthorization Act [SARA] right-to-know information). All SEFs were separated into categories based on the definition - sources, transport pathways, and landscape features. An example SEF categorization is provided in Table 5-1. Sources are related to expected transport pathways and known landscape features as a part of the ranking process. In the final ranking, source, transport pathway, and landscape feature rank were combined based on observed connectivity. The total ranks were assigned by simple addition of numerical scores assigned to each category; thus, the higher the value, the greater the probable risk.

TABLE 5-1
CATEGORIES OF ENVIRONMENTAL FEATURES AND CRITERIA USED FOR RANKING OF SEFS

SEF Category	Representative Environmental Features	Possible Criteria for Ranking
SOURCES	**Isolated/Diffuse** • septic tanks • nonpoint sources **Small Areas** • buried tanks • small businesses/farms • homes **Large Areas** • industrial parks • subdivisions • interstate highways • railroads • golf courses • irrigation systems • large farms • sewer systems • quarries • landfills	• Area • Pollutant/contaminant present • Spill potential • Monitoring data • Loading • Quantity of stormwater runoff • Frequency of runoff • Probability of contact with stormwater • Potential for changing basin hydrology • Single vs. cumulative effects
TRANSPORT PATHS	• Natural surface channels • Man-modified surface channels • Underground channels • Rundowns/constructed channels • Detention basins/ stormwater controls	• Natural barriers to flow • Length • Flow capacity • Time of travel • Connectivity • Pollutant removal capability • Proximity to sources of concern • Connection to Fulbright Spring • Direct/indirect
LANDSCAPE FEATURE	• Geologic Features fracture zones sinkholes/depressions swallow holes losing stream reaches • Soils w/ high infiltration rates • Areas w/ high groundwater • Lakes/reservoirs • Known recharge areas	• Permanent/temporary • Connectivity • Proximity to sources of concern • Potential for pollutant removal • Access/public safety

The following is a summary of the WWE SEF identification and ranking process:

Step #1 - SEF Identification/Specification

1. Identify SEF location:

    - Locate SEF on base map
    - Develop location descriptor
    - Define area
    - Relate to surroundings (distance from other SEFs, slope, etc.)

2. Identify SEF type[3]:

    - Source

        - Continuous/intermittent
        - Pollution potential
        - Frequency of pollution
        - Effective pollution production area

    - Transport

        - Transport path defined/undefined
        - Direct/indirect path to landscape feature
        - Time of travel

    - Landscape feature

        - Permanent/temporary
        - Expected connectivity with sources and transport paths
        - Access - public safety risk

[3]Consider whether subject to change with development. Identification will be based on qualitative analysis consistent with a reconnaissance-level assessment.

3. Specify SEF characteristics (primary emphasis connectivity and frequency):

   - Relate potential sources, transport paths and landscape features to specify SEF connectivity

     - Define spatial factors - > distance between source and landscape feature
     - Define temporal factors - > frequency of occurrence (continuous flow, stormwater driven, spill, or infrequent)

Step #2 - Connect SEF Character with Critical Water Quality Issues

1. Identify critical water quality issues associated with SEF (analysis will first determine water quality issues associated with a single feature or category within an SEF):

   - Presence of pollutants/contaminants
   - Expected loading
   - Expected consequence

     - Human health consequence (criteria exceedance evaluation) environmental consequence
     - Possible direct toxicity - > short-term receiving system effects
     - Possible indirect toxicity - > long-term watershed-level effects
     - Physical nuisance production (associated public safety issues)

2. Identify critical water quality issues associated with readily defined SEF connections:

   - Perform simple addition of loading for connected features and/or related SEF categories to develop "total" impact assessment

   - The primary focus of this analysis will be identification of connections to Fulbright Spring and determination of frequency of occurrence of any event that may degrade water quality

Step #3 - Rank SEFs Based on Expected Risk to Water Quality Degradation

For each category of SEF determine a potential for water quality degradation and score on a scale of 0 to 5 (where 0 = none/low potential and 5 = high potential):

1. Source

   0 = No known pollutants[4] present
   1 = Pollutants present; no obvious loading
   2 = Pollutants present; loads low
   3 = Pollutants present; loads moderate
   4 = Contaminants[5] present; loading infrequent; low stormwater and/or spill potential
   5 = Contaminants present; loading frequent or continuous; high stormwater and/or spill potential

2. Transport Path - Transport paths have been divided to include natural or artificial channels and overland flow patterns associated with landscape features with internal drainage:

   - Channels

     0 = No defined channel or transport path
     1 = Poorly defined channel; flow intermittent (mainly in storm events)
     2 = Defined channel; flow intermittent
     3 = Defined channel; continuous flow; long distance (>5 miles) from identified landscape feature
     4 = Defined channel; continuous flow; moderate distance (1-5 miles) from identified landscape feature
     5 = Defined channel; continuous flow; short distance (<1 mile) from identified landscape feature

[4]Pollutants are natural or man-made substances that typically do not produce direct toxicity, including sediment, nutrients, urban runoff, and other non-point related sources.

[5]Contaminants are typically man-made or processed natural substances that can produce direct toxicity. Contaminants include toxic organic compounds, toxic metals, and other compounds typically associated with point sources. Excess loading of a pollutant, which produces direct toxicity, will be considered a contaminant.

- Overland flow/Internal drainage

  1 = Sheet flow over natural/undisturbed ground
  2 = Sheet flow over disturbed ground; vegetation present; path generally long
  3 = Sheet flow over disturbed ground; impervious material common; path short
  4 = Flow directed through channel or conduit; some natural barriers to flow exist; path generally long (> 2000 feet)
  5 = Flow directed through channel or conduit; no impediment to flow; path generally short (< 2000 feet)

3. Landscape Features

  0 = Landscape feature is isolated with no known connection to Fulbright Spring
  1 = Landscape feature with unknown/uncertain connection to Fulbright Spring
  2 = Landscape feature suspected of having an indirect connection to Fulbright Spring; connection long or natural impediments to flow exist
  3 = Landscape feature known to have an indirect connection to Fulbright Spring
  4 = Landscape feature suspected of having a direct connection to Fulbright Spring; connection may be long or natural impediments to flow exist
  5 = Landscape feature is known to have a direct connection to Fulbright Spring

Note: Ranking will generally identify SEFs with: (a) a high risk of water quality degradation identifying a need for remedial action, (b) an expected, but undetermined risk of water quality degradation calling for further study and possible BMP application, or (c) no or low expected risk calling for a low priority for further study and management action. This information has been generated in tabular form as shown in Table 5-2. Before any specific SEF findings are presented or discussed, however, a more refined application of the procedures will be required.

TABLE 5-2
WORKSHEETS USED FOR SOURCE RANKING

MAP REFERENCE #_____

WORKSHEET FOR SOURCE RANKING

SHEET____ OF _____ DATE__/ /__
BY_____

Identified SEF (#, location, and descriptor)		SEF Type (isolated, small, large)	Critical Water Quality Issue (yes/no; if yes, description)	Assigned Ranking (1-5)	Related Ranks Trans. Path	Related Ranks Feature	Total Ranking	Comments
1	Gas Station	Isolated	Yes; Spills, leaks	4	2	5	11	Sink Drainage

TABLE 5-3
WORKSHEET FOR FEATURE RANKING

MAP REFERENCE #_____

WORKSHEET FOR FEATURE RANKING

SHEET_____ OF _____ DATE__/__/__
BY_____

Identified SEF (#, location, and descriptor)		SEF Type (isolated, small, large)	Critical Water Quality Issue (yes/no; if yes, description)	Assigned Ranking (1-5)	Related Ranks Trans. Path	Related Ranks Source	Total Ranking	Comments
F8	Small Sink	Small	---	4	2	5	11	Sink Drainage

TABLE 5-4
WORKSHEET FOR TRANSPORT PATH RANKING

MAP REFERENCE #_____

WORKSHEET FOR TRANSPORT PATH RANKING

SHEET_____ OF _____ DATE__/ /__
BY_____

Identified SEF (#, location, and descriptor)		SEF Type (isolated, small, large)	Critical Water Quality Issue (yes/no; if yes, description)	Assigned Ranking (1-5)	Related Ranks Feature	Related Ranks Source	Total Ranking	Comments
P8		Small	—	4	—	5	9	Sink Drainage

5.3 EXTENSION OF SEF RATING SYSTEM TO FUTURE LAND USE

Land use projections discussed in Chapter 1 show that approximately 3,800 acres of land are projected for additional development as residential use and 1,400 acres for non-residential, industrial, and commercial use over the next 20 years. As a result of this estimate of future development, the study sponsors have noted the advantage of using the SEF identification procedure to support both general land use and site-specific planning in the Fulbright Spring recharge area. The development of the SEF identification procedure was intended by its basic structure to accommodate the expansion of the basic procedures to support such planning processes. The foundation for expansion is the simplicity of the procedure and the support for both site-specific and general analysis.

To extend the SEF process from the initial identification objective to a planning objective, the emphasis need only be shifted to a comprehensive analysis of transport paths and landscape features to identify areas at increased risk of degrading Fulbright Spring water quality. Once these areas have been identified, control options for sources can be developed (either through planning or BMP application). In fact, a planning map can be easily developed that, based on the proposed rating scheme, will identify areas where development activities that have a high potential for pollutant and/or contaminant generation should be limited. This map would first identify the landscape features with a rating of two or above. Then, the transport paths leading to this feature would be rated. As in the initial SEF identification process, the two scores would be added to identify relative risk. This scheme is likely to produce a rating that decreases with distance from the landscape feature with zones of risk defined by changes in the rating scheme.

Although the basic mechanism for a SEF-based planning process is in place, there is still some development required for full implementation. The major focus of this development should be the rating scheme. First, the rating scheme must be reviewed to incorporate specific planning objectives and/or additional technical support to meet planning needs. Next, the issue of uncertainty must be addressed. Uncertainty is associated with feature description and actual connection to Fulbright Spring and the actual transport potential (consider this issue in light of the inherent uncertainty associated with storm events, which may control transport). Finally, the rating scheme must be tested. This testing should include field verification and long-term monitoring. In addition to the rating scheme, attention should be given to map development. Since the initial analysis was performed on section maps, there is a need for edge mapping and verification of feature/path concordance. As a final note, it should be recognized that the identified needs should not prevent immediate application of the SEF process to land use decision-making. The procedure is simple and open, allowing it to evolve with identified capabilities and needs.

CHAPTER 6
PROJECTED CHANGES IN SPRING WATER QUALITY

6.1 PROBABLE SPRING WATER QUALITY IF THE STATUS QUO PREVAILS

The project sponsors have already determined that it is an important goal to protect Fulbright Spring so that it will continue to serve as a component of the City's raw water portfolio; consequently, a water quality management program for the Fulbright Spring recharge area is necessary. After reviewing the available data on geology, hydrogeology, spring quantity/quality and after conducting the analysis of sensitive environmental features, WWE was asked by the study sponsors to address perhaps the key question in the Phase I study: In the absence of control measures of some sort, what will happen to the water quality of the spring? All of the members of the WWE consulting team have concluded, with a very high degree of certainty, that if no special actions are taken to protect Fulbright Spring water quality, basin development will result in significant spring water quality degradation. Levels of conventional pollutants would increase and organic compounds would be detected at the spring with increasing frequency.

The following discussion briefly reviews the risk factors that lead to this conclusion:

1. Surface flows readily enter the shallow groundwater system. This is apparent by the behavior of Fulbright Spring during wet weather conditions, which demonstrates that spring flows increase significantly, along with constituent concentrations for such parameters as turbidity, total suspended solids, nutrients, metals, coliform and other compounds. There is such a pronounced relationship between surface flows and flows at Fulbright Spring that, in terms of water quality management, it is more appropriate to view Fulbright Spring as a surface water supply source than as a groundwater supply source. Factors which lead to direct linkage between surface and shallow groundwater sources in the recharge area include fractures, faults, lineaments, sink holes, losing reaches of stream, areas of natural ponding, limestone outcrops, and relatively thin soils.

2. Once pollutants have been introduced to the shallow groundwater system, they will travel rapidly to Fulbright Spring and will not experience significant loading reductions while in transit. In contrast to an alluvial aquifer in which there are many physical, chemical and biological mechanisms available for reducing constituent concentrations, such mechanisms simply are mostly unavailable in this shallow limestone aquifer. Travel times

in the Fulbright aquifer are not measured in terms in feet per day but rather in terms of feet per minute, another important risk factor.

3. Fulbright Spring is susceptible to contamination from surface flows on essentially a constant basis. With an average annual precipitation of 43 inches, Springfield is a wet setting. Rainfall occurs frequently in all 12 months of the year. This is not a situation in which a community can plan in advance for "down time" for a certain water supply, while shifting to other sources.

4. The SEF analysis described in Chapter 5 of this report clearly demonstrates that there are literally innumerable locations in the recharge area that pose risk to the spring by virtue of their proximity to defined transport pathways and/or geologic features that permit direct entry into the shallow groundwater system. If the hydrologic characteristics of the basin were such that particularly hazardous zones were relatively isolated or at least focused in a certain area, the risk, as determined by the SEF procedure, would be smaller than it actually is.

5. There is ample evidence from around the United States that "typical" urban stormwater runoff contains elevated concentrations of many parameters that pose concern from the standpoint of a raw water supply for domestic purposes, and that as areas become increasingly urbanized, stormwater quality deteriorates. 1995 projections by the City of Springfield Planning Department indicate that the Fulbright Spring recharge area (or watershed) is expected to experience significant growth over the next 20 years. Specifically, 3,800 acres of additional residential development are anticipated and 1,400 acres of commercial, industrial and commercial/industrial development are projected. These are substantial figures when one considers that the tributary drainage area to the spring is approximately 18,000 acres. The South Dry Sac Sewer Trunk line completed in 1994 will also facilitate this growth.

   Constituents in stormwater runoff that commonly exhibit elevated levels include, for example, total and fecal coliform and other pathogens; heavy metals; oil and grease; total suspended solids and turbidity; nutrients; salts, and others. Table 6-1 and Figure 6-1 show data collected by Pitt (1991) and Horner and Mar (1982). A comparison of concentrations of the various parameters from parks versus commercial areas or construction sites shows clearly how development affects runoff quality. TSS particularly well illustrates the

TABLE 6-1
TYPICAL POLLUTANT LOADINGS (LBS/ACRE/YR)
FROM URBAN LAND USES

Land Use	TSS	TP	TKN	NH3	NO3	BOD	COD	Pb	Zn	Cu
Park	3	0.03	1.5	NA	0.3	NA	2	0.005	NA	NA
Low-density Residential	10	0.04	0.03	0.02	0.1	NA	NA	0.01	0.04	0.01
Medium-density Residential	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
Parking Lot	400	0.7	5.1	2	2.9	47	270	0.8	0.8	0.04
High-density Residential	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	2.4	7.3	0.5
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	4.5	2.1	0.37
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Construction	60000	80	NA	NA	NA	NA	NA	NA	NA	NA

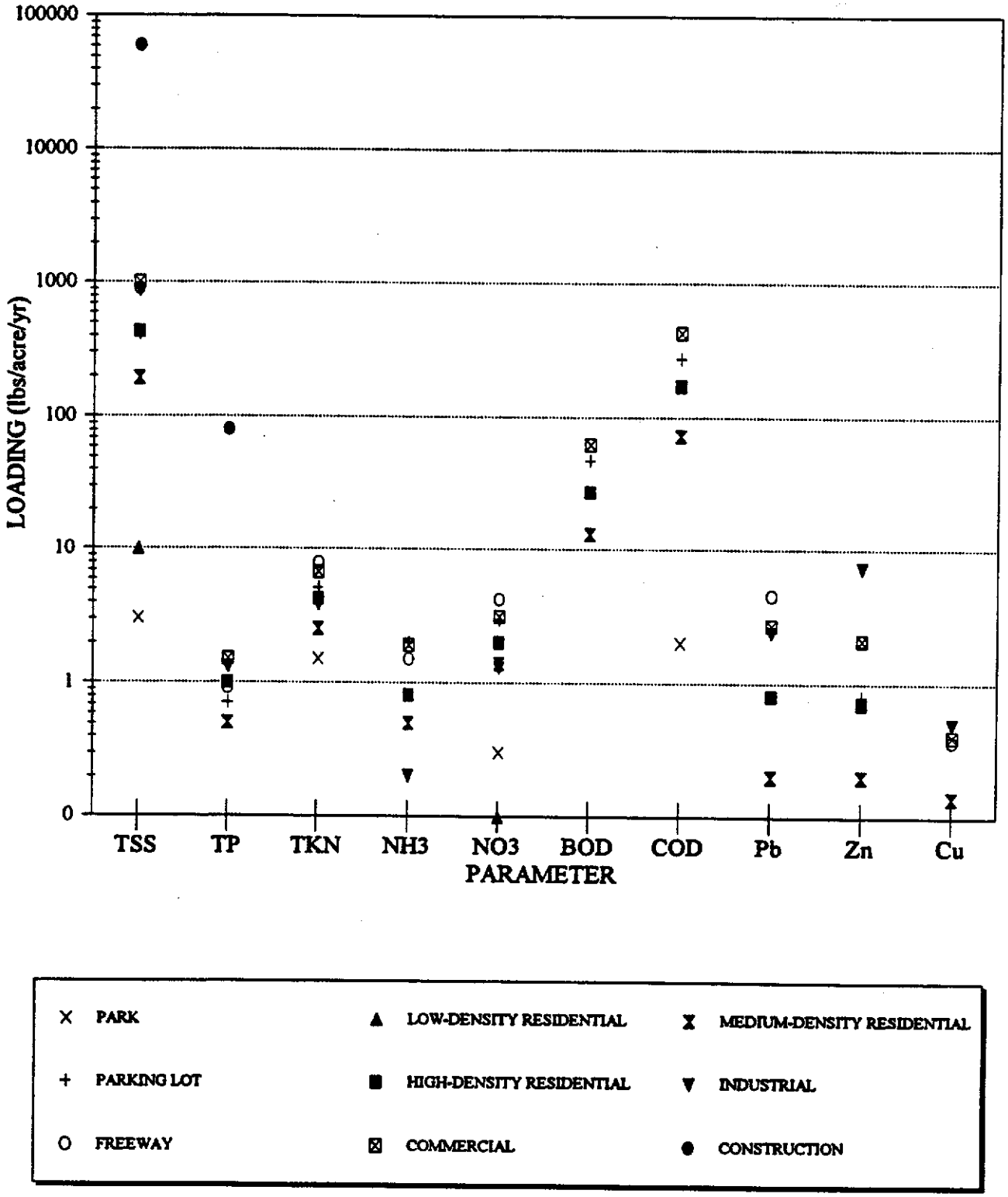
KEY:

BOD Biochemical Oxygen Demand
COD Chemical Oxygen Demand
Cu Copper
NA Not available
NH3 Ammonia
NO3 Nitrate
Pb Lead
TKN Total Kjeldahl Nitrogen
TP Total Phosphorus
TSS Total suspended solids
Zn Zinc

Sources: Pitt 1991; Horner and Mar 1982

FIGURE 6-1 TYPICAL POLLUTANT LOADINGS FROM URBAN LAND USES

SOURCE: PITT, 1991: HORNER AND MAR, 1982



problem. Data collected by the City of Springfield over the past three years as part of its stormwater-related NPDES permit application process also demonstrate raised levels of these constituents.

Data collected in the early 1980's in the NURP demonstrate that many man-made organic pollutants are found in urban stormwater runoff. The NURP program consisted of 26 cities and counties from around the United States collecting runoff samples from multiple locations over a period of 1 to 2 years. Samples were collected from various kinds of land use, including open space, residential, commercial, industrial, and "mixed." The resulting database contains thousands of entries. The data have been extensively analyzed by the EPA and contractors to the EPA, the USGS, and other parties. In general, recent data collected by those American cities and counties with populations larger than 100,000 which need to acquire stormwater-related NPDES permits are consistent with the NURP data.

Table 6-2 summarizes the key points associated with the NURP report that have significance for the Fulbright Spring area. The referenced tables and figures can be found in Appendix 8 of this report.

Organic compounds that are listed as EPA priority pollutants certainly pose concern from the standpoint of raw water supply for the City of Springfield, and such compounds are likely to be occasionally detected in stormwater runoff in the Fulbright Spring recharge area.

6. Stormwater runoff data collected from around the United States also demonstrate that as the percentage of impervious area within a drainage basin (especially directly connected impervious area) increases, pollutant concentrations in stormwater runoff increase. In the absence of appropriate controls, both the total percent impervious area and extensiveness of directly connected impervious area will increase in the recharge area.

7. One of the more important axioms that public water suppliers across the United States utilize is that land development in watersheds that are tributary to raw water supply sources (normally reservoirs) should be strictly limited. Most citizens in Springfield will be familiar with the fact that public water supply watersheds are normally well signed and that certain controls almost always apply in such watersheds. They will also be aware of the fact that there is normally very little development in such watersheds. The

TABLE 6-2
SUMMARY OF KEY POINTS FROM NURP STUDY

Conclusion/Observation That Can Be Drawn From Data	Relevant Page or Pages in NURP Report*
The majority of the 110 constituents that are listed as EPA "priority pollutants" are found in samples[6] of stormwater runoff. Furthermore, many of the organic priority pollutants have been detected in urban stormwater runoff.	Tables 6-19 and 6-20
Two organic compounds were found in 20 to 49 percent of the relevant NURP samples that were collected while 11 organic compounds were detected in 10 to 19 percent of the relevant NURP samples. If these percentages were applied to runoff in the Fulbright Spring recharge area, they would generate concern since the spring is used for public water supply.	Table 6-21
The NURP report demonstrates that many priority pollutants found in urban stormwater runoff exceed recognized criteria and standards including maximum contaminant levels under the SDWA. An important limitation associated with Table 6-21 is that the SDWA MCLs that applied in 1983 are far fewer in number than the MCLs that apply in 1994. Hence, the list of regulated organic compounds would be increased relative to that shown on this table.	Table 6-21 (Many organic priority pollutants were detected in the relevant NURP samples with frequencies ranging from 1 percent to 9 percent.)
As the development density (percent impervious area) increases, pollutant loading also increases.	Table 6-25
Residential stormwater runoff can be a significant source of pollutants and this is an important observation to acknowledge given the projected land use in the Fulbright Spring recharge area.	Table 6-25 and Figure 6-18

*See Appendix 8 of this report

[6]The NURP program consisted of 26 cities and counties from around the United States collecting stormwater runoff samples from multiple locations over a period of 1 to 2 years. The 26 participating communities were spread throughout the continental United States. Samples were collected from all representative kinds of land use including open space, residential, commercial, industrial, and "mixed." The resulting database contains thousands of entries. The data have been extensively analyzed statistically by the EPA and contractors to the EPA, the USGS, and other parties. In general, data collected by those American cities and counties with populations larger than 100,000 which need to acquire stormwater-related NPDES permits are consistent with the NURP data. The NURP database is generally recognized as the most authoritative, large-scale sampling effort of urban stormwater runoff that has been conducted.

development that already exists in the Fulbright Spring recharge area contradicts this basic axiom. Further development, especially in the absence of controls, would even more strongly contradict this axiom.

8. In October 1994, the CU Central Laboratory performed screening tests in areas around lower Pearson Creek for VOCs. Levels of TCE (3.5 ppb) were found in the creek, as well as 11.5 ppb in Jones Spring. Also found in Jones Spring were detectable levels of bromodichloromethane, chloroform, 1,1-dichloroethane, 1,1- dichloroethene, 1,1,1-trichlorethane, and tetrachloroethylene.

   It should be emphasized that this watershed is separate and distinct from the Fulbright Spring recharge area. Nonetheless, the results are relevant as an indicator of how ground and surface water quality may be affected as Fulbright Spring urbanizes. This subbasin is highly urbanized and there are many potential sources of pollutants, including a landfill. However, these specific compounds are typical of industrial processes that use such solvents (metal-finishing, metal cutting, pharmaceutical manufacturers, and others). These data are provided in Appendix 8.

9. Consistent with most other American communities, stormwater management in Springfield has traditionally focused on flood hazard reduction ("quantity" management) rather than on stormwater quality management. There are significant differences between stormwater quantity and quality management. Stormwater quality control focuses on many objectives that are not relevant from the standpoint of drainage and flood control. These include strict attention to pollutant source controls, minimizing directly connected impervious area, capturing, storing and treating only a small amount of rainfall (under many conditions the first ½-inch of runoff contains the highest pollutant concentrations during a storm), storing stormwater for extended periods to facilitate the physical, chemical, and biological removal of pollutants. These kinds of stormwater quality management practices are not yet evident in the Fulbright Spring recharge area and this is a risk factor.

10. There is already considerable development in the basin and there are numerous pollutant sources of potential concern. There are significant industries, railroads, four lane highways, trucking facilities, a golf course, significant numbers of businesses, residential housing and farmland. It is important to recognize that any watershed management program for Fulbright Spring cannot start with a "clean slate." To the contrary, the

starting condition is one that includes a significant amount of preexisting development. Hence, the "margin of error" is smaller than it would be in a virgin basin.

For all of these reasons, WWE has concluded that in the absence of control measures, spring water quality will deteriorate. Because the study sponsors have established the goal of protecting spring water quality such that the spring will continue to serve as a raw water supply without the addition of sophisticated treatment processes to the current water treatment facilities, there is clearly the need to formulate, implement and maintain a sound watershed management plan. There is still time available to do this, but it is the opinion of WWE that the window of available time is small.

6.2 SPRING HYDROLOGY

The focus of this Phase I study has been on protecting Fulbright Spring water *quality*. WWE has *not* evaluated how the hydrology of the spring is likely to change as the area develops. During Phase II, however, this would be a valuable subject to address. Given the projected nature of development for the spring recharge area, and even though new developments will reduce recharge potential, it appears to WWE that even when the basin is "built out" as defined by the *1995 Draft Land Use Plan*, there will be more than enough recharge occurring to assure that springflows are adequate to sustain the City's anticipated water demand.

CHAPTER 7
NONSTRUCTURAL BEST MANAGEMENT PRACTICES

7.1 INTRODUCTION

In the course of conducting this Phase I level investigation of Fulbright Spring, members of the WWE team have reviewed over 100 reference books and articles on stormwater quality control programs that have featured varying combinations of structural and nonstructural controls. We have interviewed dozens of recognized experts nationally. We have retained Mr. Earl Shaver, Director of Stormwater Management for the State of Delaware, and Mr. Eric Livingston, Director of Stormwater Management for the State of Florida, to "peer-review" our findings. Based upon our interviews, literature review and peer-review, *there is no question that in order to attain the ambitious goal of strictly limited degradation of spring water quality, a watershed management program consisting of nonstructural controls and structural BMPs and monitoring will be necessary.* Neither the interviews that we conducted nor the literature reviewed clearly support emphasizing nonstructural controls over structural controls, or vice versa. Although a blend of the two practices will be necessary to protect spring quality, during the early stages of the watershed protection program, there should be strong emphasis on certain nonstructural approaches as defined here.

7.2 PROTECTION OF FULBRIGHT SPRING AND THE SOUTH DRY SAC RIVER WATERSHED

7.2.1 INTRODUCTION

Protecting the water quality within the Fulbright Spring/South Dry Sac River watershed will involve a comprehensive stormwater management program which should include both structural and nonstructural BMPs. Nonstructural BMPs include land use restrictions, overlay zones for a variety of regulations, pollution prevention programs and education, changes in procedural and institutional policies, etc. There is little or no actual construction of facilities, although the definition of how structures or other improvements may be designed could be a part of the regulations. Structural BMPs are physical facilities that control, divert, retain, and/or detain runoff. Additionally, the structural BMP should provide some level of stormwater quality mitigation; in fact, this becomes the key issue in the Fulbright Spring recharge area.

The local soils and geology create a watershed which is vulnerable to water quality problems. These limitations will make it very important for the public, elected officials, and others involved with the development of this area to realize these limitations and support actions needed to protect the local water resources. Thus, the two keys to protecting this resource are sound land use planning and controls along with a comprehensive program of public education.

Protection of any watershed is easier before development occurs and when all alternatives are available. As development proceeds different mitigation measures become ineffective or are almost impossible to implement due to costs or acceptability. Thus time becomes the enemy of the municipality trying to protect critical resources. Early planning, decisions and implementation are essential if effective and economical solutions are to be implemented.

In any urban watershed, pollution of the surface and groundwater is determined by pollution sources and pathways for the pollution to reach the water resources. Thus, if pollution sources are eliminated, resulting pollution of the water resources will be eliminated. Likewise, if pollutants do not have a good pathway to the water resources, their impact on pollution of these resources will be mitigated. From our study, indications are that the existing development has created some pollutant sources but these sources are located where good pathways to the groundwater supply are not available. Thus, the area has been very fortunate in that the groundwater in the recharge area does not show signs of major pollution at this time. Future development, if not properly controlled and sited, may have very different effects on the water quality of the area.

Appendix 4 gives a description of nonstructural BMPs that have potential application within the Fulbright Spring/South Dry Sac River watershed. Appendix 7 gives a description of structural BMPs that have potential application within the watershed. Following are some general discussions concerning the protection of Fulbright Spring recharge area and the use of both nonstructural and structural BMPs.

7.2.2 DEVELOPMENT PRESSURES

It is inevitable that water quantity and quality changes will occur in the Fulbright Spring recharge area as urbanization continues. It is not possible to stop urbanization, but it is feasible to enact controls to mitigate adverse impacts and to allocate the costs for this mitigation to those responsible and those who will obtain the benefits. As with most environmental problems, it is easier and more cost effective to implement appropriate management techniques before major

problems occur than to correct problems after damages are done. Water quality control in the Fulbright Spring recharge area is an excellent example of this point. Keeping sediment on construction sites, preventing pollutants from entering the local drainage systems, educating citizens on the proper use of potential pollutants, etc. are easier to implement and less costly than removing pollutants within the drainage system or at the water treatment plant. Although a combination of structural and nonstructural BMP approaches is usually needed and appropriate, the nonstructural, cheaper, and less extravagant BMPs should be used first and should be the first line of defense against pollution of the local water resources. In addition, nonstructural BMPs can be thought of as pollution prevention measures while structural BMPs are used for pollution control.

7.2.3 DEVELOPMENT IS THE KEY

The local development process holds the key to successful protection of the Fulbright Spring recharge area. If properly enforced, the land use plan for the recharge area can incorporate effective nonstructural BMPs which will be inexpensive to implement and will not require major maintenance and other long-term costs. Also, if properly planned, these BMPs can be incorporated into new development without causing major increases in development costs and without creating difficulties related to maintenance, safety, aesthetics, and other factors of this kind. Examples of such BMPs include buffer zones, incorporation of undeveloped areas within the development and limitations on the use of impervious surfaces. By using cluster development, overlay zoning, stream conservation districts, planned unit development (PUD) and other modifications to the normal zoning restrictions, developers can obtain the same development densities but leave undisturbed areas and buffer zones for pollution control and decrease the infrastructure needs of the development, with a resultant decrease in the amount of impervious area within the development. In addition, disconnecting impervious areas such a roof drainage and small parking areas can be easily implemented if incorporated into the initial development design.

Another option that can be incorporated into land use planning is utilization of several stream corridor management options. These options include purchase of critical areas, establishment of special improvement districts, acquisition of easements, watershed specific rules, etc. It is anticipated that future planning and analysis phases of the recharge area will identify critical areas where it will be extremely important to provide safeguards to protect the groundwater supply. These safeguards may not be needed in other areas and implementation on a watershed wide basis

may be more costly than the benefits received. However, their implementation within selected areas may be a very effective way to protect the local water resources.

Land use controls will be different for different purposes (e.g., water quantity control, water quality control, erosion and sediment control). For water quantity control all impervious surfaces may contribute to the peak flows and volumes while for water quality control only directly connected impervious surfaces may be involved. Also for water quantity control large floods are usually of most concern while smaller floods dominate the control strategies for quality and sediment control.

Thus, proper land use planning is a critical element in the protection of the recharge area and this planning should include some form of impervious area limitations.

7.2.4 TYPE OF DEVELOPMENT

It will be important to have a plan for the watershed which specifies the types of development that will be allowed within the watershed. Generally, the goal is to minimize the amount of impervious area within the watershed, especially impervious areas that are directly connected to the surface drainage system and the groundwater system. There are several criteria that can be used to reach this goal.

1. Review requirements for road widths and see if they can be reduced without jeopardizing public health or safety. One subdivision in Delaware reduced its road impervious area acreage by 20 percent by reducing the width of the interior roads.

2. Requirements for curbs and gutters and enclosed storm drain systems should be evaluated. Encourage the use of vegetated swales rather than curbs and gutters and incorporate storage within the swales where practical. Swales can also be used in commercial and industrial areas.

3. Promote the use of alternative parking lot material such as sod or gravel, turf blocks, pervious pavements, etc. These are especially appropriate on parking spaces that are rarely used and which are farthest from the store. Assure that commercial parking requirements do not lead to extensive parking lots which are seldom used.

4. Investigate the possibility of having roof area runoff, generally considered cleaner than parking lot runoff, directed to dry wells or infiltration basins to maintain recharge rates.

5. Require all runoff from impervious surfaces to be directed over pervious areas before entering the drainage system.

6. Planned unit type developments should be considered in some areas in order to minimize the amount of associated impervious areas.

7.2.5 IMPERVIOUS AREA LIMITATIONS

One of the most effective ways to protect the groundwater within the recharge area is implementation of impervious area limitations. Impervious areas are a major pollutant source and provide an efficient pathway for storm runoff to enter the local drainage systems and eventually the groundwater supply. Many municipalities that are dealing with water supply watersheds are developing and implementing impervious area limitations.

The City of Austin, Texas has chosen to manage the impact of new development in two fundamental ways: through control requirements and impervious area minimization requirements. Austin, through its Comprehensive Watershed Ordinance, requires that impervious cover on residential development in certain areas of the city be limited to 15 to 25 percent. Sedimentation and filtration ponds which will capture and treat the first ½-half inch of runoff from a site are required for developments of higher intensity, such as commercial developments.

In compliance with state water supply watershed regulations, municipalities in North Carolina have adopted impervious area limitations. These limitations are quite complex since there are five different classifications of watersheds, depending on the amount of existing development. However, following are the general requirements:

<u>Critical Areas (near water supply points)</u>
12 percent impervious area without structural BMPs
12 to 30 percent impervious area with structural BMPs

<u>Entire Watershed</u>
24 percent impervious area without structural BMPs
24 to 50 percent impervious area with structural BMPs

Impervious area limitations should be carefully developed for the recharge area to balance the objectives of groundwater protection without implementing unreasonable and ineffective impervious area limitations. Further detailed analysis would be needed before a recommended impervious area limitation plan could be developed for the recharge area.

7.2.6 PROTECTION AND/OR ACQUISITION OF CRITICAL AREAS

1. To the maximum extent practical, buffer zones should be required around sinkholes, springs, fractures, and other geologic features that provide entry points for surface water into the shallow groundwater system. In addition to buffer zones, minimum setbacks should be considered. The recently passed 100-year volume protection zone is certainly a good beginning to develop buffer zone requirements. This requirement should be carefully monitored and modifications implemented as evidence indicates that the zone is either too large or not large enough.

2. Minimize the amount of land which is cleared when developed. This can be accomplished through local regulations requiring a minimum area of a site to be maintained in a natural condition (i.e., Tallahassee requires 20 percent) or by having scheduling and staging of construction.

3. Limit development on steep slopes and areas where soils are very unstable.

7.2.7 MONITORING PROGRAM

One of the major mistakes made over the past twenty years in the implementation of stormwater management quantity programs is the lack of monitoring and feedback of results. Ordinances, regulations and other program elements have been adopted, and it was assumed they were accomplishing the objectives of the programs. It is critically important that a monitoring program be part of the actions taken to protect the groundwater within the recharge area. The design of BMPs, use of impervious area, and buffer zone limitations all incorporate some technical judgment and will require the results of a monitoring program in order to make proper adjustments to protect the groundwater supply and/or lessen the requirements for certain urban developments. This monitoring program should be designed and implemented as soon as possible in order to obtain baseline data for future comparisons.

The most critical element of a monitoring program is the establishment of clear, concise monitoring goals. An initial possible list of monitoring goals is provided:

1. Determine baseline conditions for both ground and surface waters. This should include sites in the headwaters of the recharge area, above and below existing and potential pollutant sources, above and below proposed BMP and pilot study sites, and at the downstream end of the area. Optimally, baseline data for future intensive monitoring (such as BMP sites) should be gathered for at least three years prior to BMP testing (Spooner *et al.* 1991);

2. Determine long-term temporal and spatial trends in water quality throughout the basin as development proceeds in order to determine the need for more controls on land use and controls and structural BMPs;

3. Determine short-term trends (including transient loadings of EPA priority pollutants) in water quality at specific sites to establish quantitative criteria for the relationship between hydrological events and water quality in the groundwater and Fulbright Spring. Previous monitoring in the Fulbright Spring area has been far too spatially and temporally disconnected to determine transient trends in pollutant loading such as stormwater discharge loadings or pollutant "pulses";

4. Determine the trends in water quality upstream and downstream from new structural or nonstructural BMPs and pilot study areas; and

5. Determine baseline and trend information on riparian biological communities as general indicators of the health of surface waters.

This is only an initial accounting of the goals that may apply to the Fulbright Spring recharge area. A thorough analysis would depend on informational requirements of the laws and regulations in effect and proposed for the area, informational needs of those impacted by the water quality of Fulbright Spring and receiving surface waters, and the information needs of the water quality managers (including CU and other study sponsors, county planners, etc.) These goals must also be evaluated in terms of attainability. For example, a useful goal would be to identify and track any spill or pollutant pulse anywhere in the watershed at any time. This would require a sampling frequency (both spatial and temporal) that would be enormously expensive. Instead, one should attempt to track pollutant loadings during wet weather at specified points.

The use of volunteer monitoring can be particularly effective in an overall monitoring program. This may be especially true for short-term water quality studies. During storm events, it is difficult to provide enough samplers to track the spatial and temporal trends of pollutants through the watershed. By utilizing a volunteer sampling group that can respond to such events, the necessary data can be collected without great expense. Volunteer monitoring is most effective if *consistent, well-defined, sample collection and storage protocols* are established and strictly followed. Also, parameters such as suspended solids can be used as indicators of other parameters that are more difficult to collect and more expensive for lab testing. Finally, these volunteer groups can be used in bio-monitoring as well.

A well-designed monitoring system can provide the information needed to manage the Fulbright Spring recharge area and provide solid technical information to back up regulatory decisions. A program that is hastily assembled without careful consideration of long-term and short-term goals and how the data is to be analyzed will result in a program that provides a very high ratio of dollars spent to useful information gathered. This is only a cursory look at the process of designing a water quality monitoring system, and more effort must be put into this task (specifically in a Phase II study).

7.2.8 POLLUTION PREVENTION

Once sediment and other pollutants enter the drainage system it will be very difficult to control water quality problems. Thus the goal is to prevent (or, normally, to significantly reduce) pollution from occurring in the first place, rather than relying on BMPs to control pollutants within the drainage system. This is where public education plays a very important part in order for the citizens, elected officials, and businesses within the watershed to understand the tremendous potential for NPSs to contaminate the groundwater resource. Actions in this area include the following.

1. Street and parking lot sweeping using vacuum sweepers.

2. Detecting and eliminating illicit connections to the stormwater system.

3. Proper handling, use, and disposal of fertilizers and pesticides. Even better, use "natural landscaping" that requires minimum use of chemicals.

4. Encouraging proper handling, use, and disposal of household chemicals and pet wastes. Establishing household hazardous materials recycling and waste disposal centers.

5. Requiring businesses to develop pollution prevention plans and employee training on proper use and disposal of materials that are potentially damaging to groundwater.

6. Businesses should review materials, especially solvents and other liquids, used in processing and try to find replacements with less hazardous materials.

7. Proper siting, storage, and, where necessary, containment of materials should be required. For example, loading docks, storage areas, and equipment maintenance and storage areas are good areas for roofing to minimize exposure to rainfall and runoff.

8. Carefully siting snow storage areas so that runoff or seepage from the snow pile does not harm waters and is properly treated before discharge.

9. Minimizing or eliminating the use of salt (sodium chloride). Alternatives include sand, calcium magnesium acetate, calcium chloride, etc.

10. Storing salt properly which means away from critical or sensitive areas, on impermeable surfaces, and under a roof.

11. Public education is an important part of pollution prevention. As an example, worker education programs for areas such as the Friendship Industrial Park will help prevent pollution of groundwater from actions that could be easily avoided if the workers were made aware of proper procedures and the possible effects on the local water resources of their actions within the workplace.

One of the major advantages to pollution prevention is that it is usually much easier to enforce pollution prevention measures than other BMPs. In addition, pollution prevention is probably the most cost effective solution, e.g., when sediment leaves a site, the battle is largely lost and mitigation measures become expensive and difficult to maintain.

7.2.9 DESIGN CONSIDERATIONS

The failure of most BMPs can be related to design considerations, construction of the BMP and maintenance actions. If not properly designed the BMP will not function as desired and may cause major problems resulting in lack of pollution control and the creation of problems for local officials. As an example, if an infiltration facility is not properly designed it might not be capable of containing the proper volume of water and could result in an area that does not drain properly resulting in standing water and related insect and rodent problems.

To ensure proper design the local municipality should consider the following actions.

1. Provide documentation and guidance for the proper design of structural and nonstructural BMPs that can be implemented within the recharge area.

2. Provide the technical tools necessary for the local consultant community to design facilities in compliance with the documentation provided.

3. Provide the resources necessary to hire the staff needed for development review and inspection services.

4. Provide technical training for consultants and staff.

Proper design is critical to ensure that BMPs are constructed according to the criteria that have been reported in the literature and to incorporate the experiences of other municipal applications. In addition, proper design can help lessen the maintenance that will be required during the life of the BMP and can make this maintenance task much easier.

7.2.10 ON-SITE VERSUS OFF-SITE FACILITIES

One of the major differences in the overall design of BMPs for water quantity control and water quality control is the size and location of facilities. Over the past 20 years, small on-site water quantity facilities (i.e., detention basins) have been encouraged in many municipalities. Recently, many such facilities have been shown to be somewhat ineffective in controlling water quantity problems throughout a watershed and their major benefits have been to areas directly downstream from the facility outlet. This has resulted in a new emphasis on regional facilities for water quantity control. In contrast, small on-site facilities are more effective in controlling many

pollution problems rather than large regional facilities. Thus water quality control should concentrate on source control, even on small lots, while quantity control is usually a combination of on-site and regional facilities.

7.2.11 MAINTENANCE

Maintenance is a key element for any stormwater related program that is often neglected in many municipalities. The effectiveness of all structural and many nonstructural BMPs is dependent on adequate maintenance. In most municipalities this maintenance responsibility has been delegated to the property owner with the results that little if any maintenance is done. It is really not practical to assume that a private citizen will have the knowledge and resources to provide adequate maintenance. Thus, the municipality should assume this responsibility, provide the needed funding, and resolve issues related to easements and access when developments are being proposed. Lack of adequate maintenance will result in the failure of measures designed to protect the recharge area. It cannot be overemphasized that even the best designed BMP must receive proper maintenance if it is to perform as designed. In addition, monitoring is needed to determine the adequacy of the design, proper level of maintenance, and the resulting effects on the local water resources.

7.2.12 MASTERPLANNING

Appendix 5 contains a detailed discussion of masterplanning and how it can be used to protect the recharge area. Generally, the major purpose of masterplanning is to analyze a watershed or a major part of a watershed and develop a plan to protect the resources within the analysis area. Since the protection of the water resources within the recharge area will necessitate the use of many BMPs, it is necessary to determine not only how a particular BMP will operate but how the "system" of BMPs will together act to prevent and mitigate pollution problems. A transportation engineer would not design an urban traffic signalization system without synchronizing the individual signals so they operate as an efficient system. Likewise detention basins, channelization, impervious surfaces, etc., affect the volume and timing of runoff events and a system wide analysis is needed to control the runoff throughout the drainage area. The masterplanning effort also identifies where certain BMPs might be located and the interface between urban development and the drainage system.

Planning will be a critical element in the protection of the recharge area and masterplanning should be a major focus of the planning effort. Since developing a masterplan will take time,

some measures should be enacted before such an effort can be completed, such as nonstructural and some structural BMPs. This will reduce further degradation of the local water quality and may allow for implementation of some BMPs in the future.

It should be noted that "planning without implementation can become a useless exercise." This statement assumes that some implementation might be to do nothing or nothing more than is presently being done. However, continual funding of planning studies without some actions being taken will sometimes give masterplanning a "bad name" and may lead to complete inaction and resulting major pollution problems within the area. This can be prevented by a masterplanning process which identifies phases or stages where the planning process will produce results that can be implemented or acted upon. This concept should be thoroughly examined before the masterplanning process is begun.

7.2.13 FUNDING

If a program to protect the recharge area is to be implemented, funding will be needed. Many municipalities have enacted ordinances, regulations, and other program elements related to stormwater management without giving the Planning and Public Works Departments additional funding to implement these measures. Generally this has led to a failure to implement these measures which leads to an erosion of public confidence and enthusiasm.

Municipalities across the country are struggling to find ways to provide funding for stormwater related activities which has led to the present popularity of utilities and impact fees. These alternatives should be closely examined as means of funding measures needed to protect the recharge area. It is true that some initial measures can be taken to protect the recharge area without significant additional funds, but some funding will be needed for initial planning and investigation studies. After this, continued funding will be needed for implementation of specific measures needed to protect the recharge area.

In some cases, funds currently being spent on stormwater quantity control can be used or reoriented to solve both water quantity and quality problems. Examples might include incorporating wetlands within detention areas, designing for sheet flow rather than concentrated flow or disconnecting impervious areas from the drainage system. However, this will entail changing the way facilities are designed. It will also be up to the municipality to provide the leadership and training to effectively implement this reorientation. However funding for stormwater management within the recharge area from existing taxes, budgets, review fees, etc., will not be

adequate to implement a comprehensive stormwater management program and additional funding sources will be needed.

7.2.14 INSTITUTIONAL AND PROGRAMMATIC CONSIDERATIONS

The success of any program to control the water quality within the watershed will depend largely on the institutional framework and the support given to this framework by the local elected officials. As outlined in the previous pages, key components might include the following.

1. Masterplanning of the watershed to include land use alternatives, location of some BMPs, location of stormwater management facilities, etc.

2. Land acquisition programs to purchase sensitive areas and to purchase conservation easements or development rights.

3. Development of a comprehensive stormwater management program which includes:

    a. engineering design procedure documents related to hydrology, hydraulics, detention storage, erosion and sediment control, etc;

    b. computer models and technical aids;

    c. ordinances and regulations; and

    d. technical criteria and design standards.

4. Programs to establish and promote proper maintenance of the drainage system.

5. Inspection programs to ensure that BMPs are operating as designed and water quality levels are being maintained.

6. Education programs.

7. Development of a dedicated source of revenue.

7.2.15 LOCAL ORDINANCES AND REGULATIONS

Existing ordinances and regulations within the county and city should provide a good basis to start the protection of the recharge area but some modifications may be needed.

1. The existing ordinances dealing with detention basins need modifications related to design methods allowed, criteria used, and the integration of detention facilities throughout a local drainage area.

2. Since the hydrologic methods used affect all regulations dealing with stormwater, both quantity and quality, the recommended methods should be reviewed and updated where necessary.

3. Basic criteria used for stormwater design (i.e., peak flow, volumes) need to be reviewed and modified as needed. As an example, would it be better to control velocities of flow rather than peak discharges from future developments?

4. Maintenance considerations within existing regulations need to be reviewed and realistic determinations made concerning who will have the maintenance responsibility for different stormwater management facilities.

5. Procedures are needed to assist in determining the interrelated effects of different stormwater management facilities. As an example, how far downstream should an engineering analysis be extended to determine if the combined effects from several storage facilities will produce problems?

6. There is a need for a technical/engineering manual to provide criteria and procedures for the design of all stormwater management facilities. During the development of such a manual, existing criteria should be evaluated and modified as necessary.

7.2.16 EDUCATION

Education becomes a central focus in all of the different aspects related to protection of the recharge area. Education is discussed in Appendix 4 for the different nonstructural BMPs. Education activities should be included in the following activities:

1. Informing the local citizens, politicians, and other interested persons about the different aspects included in the recharge protection area.

2. Educating local consultants in the design and construction of nonstructural and structural BMPs.

3. Educating reviewers and inspectors concerning the design and construction of different BMPs.

4. Educating developers and others involved in the development process concerning the advantages of integrating BMPs within developments and utilizing natural features within the development area to protect local resources.

With proper education, many potential problems can be solved during the initial planning of developments and BMPs can be properly used to protect the local resources.

7.3 REVIEW OF EXISTING REGULATIONS

7.3.1 GENERAL COMMENTS

WWE has briefly reviewed the Greene County, Missouri regulations Section 314 - Grading, Sediment, and Erosion Control; Section 307 - Sink Holes and Karst Features; and the Greene County, Missouri Stormwater Committee Recommendations. In general, the ordinances seem reasonable and consistent with the practice of most American communities. Some specific suggestions include:

1. Provide background information on why erosion/ sediment control and sinkhole protection is critically important in Springfield (the water quality data for Fulbright Spring under wet weather conditions are helpful in this regard) to avoid charges of "taking" and/or over-regulation from the development community and others.

2. It could be helpful to perform a systematic comparison with the EPA's recommended criteria for BMPs and other erosion control program elements. For example, EPA recommends almost four times the sediment storage volume that these regulations do. Following EPA's recommendations (in some key areas) would certainly leave Springfield consistent with national standards.

3. Evaluate whether Greene County has enough money to adequately enforce compliance. This is the most common deficiency with erosion control programs nationally. From a cursory review of Greene County's situation, increased revenues for inspection/ enforcement would be desirable.

4. The 1993 two-day seminar (July) on erosion control chaired by Tim Smith of Greene County was excellent and should be followed up by more such seminars/training sessions. Take note of the fact that in Delaware, contractors are *required* to take a class in erosion control and inspectors must take a 40-hour training course and pass a test.

7.3.2 SECTION 313 - GRADING, SEDIMENT, AND EROSION CONTROL

General thoughts regarding these regulations:

- How are sites less than 5 acres in size addressed?
- How do these regulations apply to shorter duration (less than 24 hours), or more intense (greater than 1 inch) storms?
- The county may want to more carefully distinguish permanent from temporary control measures;
- 5 feet/second for channel velocities could be excessive and should be checked for reasonableness.

Specific recommendations include the following:

1. GENERAL: It should be stated that this document is meant to provide a minimum level of protection, though additional BMPs may be appropriate in given situations and can be used where appropriate.

2. SECTION 314.2: Two additional goals may be appropriate: (a) prevent overland runoff from off-site areas from crossing the site, and (b) slow velocity of water as it crosses the site.

3. SECTION 314.3.1: It should be made clear that temporary controls that are to become permanent controls must be fully cleaned at the end of the construction. We have frequently seen this not occur, and the permanent BMPs have significant problems.

4. SECTION 314.3.4: The soils and geologic setting is an important section for erosion and sediment control. This section should be expanded. The data available from the Natural Resources Conservation Service (NRCS) soil surveys should be discussed.

5. SECTION 314.4.1.2: It is WWE's opinion that even if an individual stormwater NPDES permit is issued for a site, the erosion and sediment control plan should still be reviewed by county officials.

6. SECTION 314.4.1.4: A 25-foot separation between a spring, sink hole, wetland, or water course and construction activities seems inadequate.

7. SECTION 314.4.4.C: The security required for public improvements ($500 per acre) appears to be inadequate. It may be appropriate to use an erosion control cost estimate prepared by the party submitting the plan as a basis for the security deposit. This cost estimate should include both the capital construction cost as well as the maintenance cost of the erosion control features.

8. SECTION 314.6.1.F: A time limit on exposure of stockpile areas would be appropriate. If stockpiles are exposed for greater than a predetermined time limit, the area should be mulched or seeded.

9. SECTION 314.6.2: A clear distinction should be made in this section regarding requirements for temporary sediment containment and requirements for permanent sediment containment. It should be made clear that the stated BMPs are a minimum that should be used. It should also be stated that other BMPs may be applicable.

10. SECTION 314.6.2.D: The stated 1,000 cubic feet per acre of runoff from a 1-inch rainfall with a curve number of 90 seems to be small.

11. SECTION 314.6.3: A clear distinction should be made in this section between permanent stabilization measures and temporary stabilization measures. Mention should be made of stabilization measures other than seeding or mulching. Attention should be paid to assuring stabilization during all times of the year. As this section now reads, there are no stabilization measures required between November 16 and February 28.

7.3.3 SECTION 307 - SINK HOLES AND KARST FEATURES

1. GENERAL: This section does not seem to relate well with the erosion control section. More reference should be made to applicable portions of the erosion control criteria.

2. GENERAL: A potential problem with this section is that restriction on building within sink holes could be construed as a "taking." This section, therefore, must effectively demonstrate that the measures stipulated herein are reasonable and effective. It must be shown that the ordinance is very specific and not arbitrary and capricious. Evidence must be given that the water quality from the spring will be impaired without effective regulations. The evidence to do this should already be available. A link must be made with Fulbright Spring and protection of public health, safety, and welfare.

3. SECTION 307.6.B: Is there a basis for the 500 feet distance between water supply sources and the site?

4. SECTION 307.8: Is the receiving groundwater use intended as present use or anticipated potential future uses?

5. SECTION 307.8.1.A: The distances for definition of critically sensitive areas seems small. Is there a specific scientific basis for these distances?

6. SECTION 307.8.2: This classification seems to leave some types of development in a gray area between hazard classifications (e.g., what about residential developments such as zoning districts R1 or R2 where the directly connected impervious areas discharging to the sink hole are greater than one acre?).

7.3.4 GREENE COUNTY, MISSOURI STORMWATER COMMITTEE RECOMMENDATIONS

1. The peak runoff rate used when allowing for drainage from upstream properties could be reduced if flow from upstream properties is attenuated through *dedicated* stormwater detention facilities.

2. Under item 6A of Recommendations for Immediate Implementation, it would be clearer to state that the culverts must be sized taking into account inlet and outlet control, with and without submergence.

3. This set of recommendations should look at regional detention facilities. At a minimum, comprehensively evaluate the effect of smaller detention facilities (through routing). Small ponds may just be delaying peak flows and not eliminating them.

4. Under item 2 of Major Long-Term Policy Goals, care should be used in recommendation of infiltration basins. These are very maintenance intensive.

7.3.5 EXISTING SOURCES OF POLLUTANTS

An important question confronting the study sponsors is to what extent, if at all, existing pollutant sources in the recharge area should be regulated. This is an issue that is commonly termed "retrofitting," and it is always one that is difficult to address, for many reasons. To begin with, from a technical standpoint, it is quite difficult to go in *after the fact* and install suitable stormwater quality control measures. Space is usually at a premium, grades have been set, utilities are in place, adjoining land uses are defined, and other constraints prevail. There are even more challenges on the nontechnical side, including, as examples: which sources are targeted and which are not; what level of control is necessary; who pays for the improvements; existing landowners "predate" new regulations, so they are not implementable, etc. Finally, there is no clear evidence from water quality monitoring data that existing pollutant sources are causing significant water quality problems. Thus, it may be difficult to justify retrofitting requirements based on the water quality issues.

After discussions with the study sponsors about retrofitting, WWE has concluded that, at least in the initial phase of the watershed protection program, retrofitting will not be feasible. Instead, the regulatory program should focus on *new* sources. With this said, however, it is important to note that during this Phase I study, members of the WWE team have comprehensively applied the "sensitive environmental feature" evaluation to *all* significant existing pollutant sources in the watershed. Therefore, if the project sponsors are interested in retrofitting at some time in the future, a good data base will exist to begin the process.

7.3.6 BUFFER ZONES AND OVERLAY ZONING

WWE has interviewed many nationally recognized experts and extensively researched the literature in the course of conducting this Phase I study. Our interviews and literature search clearly indicate that a consensus technique for protecting stream and shallow groundwater quality is to preserve undeveloped buffer zones in the vicinity of natural features of importance such as streams, fractures, faults, sink holes and others that are directly associated with the receiving water. In areas where it is not feasible to preserve buffer areas in their natural (undeveloped) form, the alternative is to impose special development restrictions, usually via the technique of "overlay zoning." Such restrictions commonly include establishing minimum setbacks of development features, prescribing limitations on chemical/pesticide usage, imposing impervious area limitations, and others of this kind. WWE has concluded that there is an excellent potential for establishing buffer zones and overlay zoning in the Fulbright Spring recharge area because so much of the basin remains undeveloped. Existing ordinances and regulations also provide a precedent in this regard.

7.4 CONSIDERATIONS REGARDING PILOT PROJECTS IN THE RECHARGE AREA

Representatives of the City Public Works Department have suggested that it might be advantageous to conduct one or more pilot projects in the recharge area to ascertain the effectiveness of both structural and nonstructural control measures. WWE strongly endorses this suggestion, because multiple objectives could be accomplished, including:

1. BMP pollutant removal efficiency data for Springfield are lacking and there is an urgent need for data of this kind for a comprehensive watershed management plan.

2. Data are also lacking regarding the effectiveness of nonstructural controls, not only in Springfield, but nationally. For example, logic indicates that strong public worker education programs and a "committed" citizenry undoubtedly reduce the likelihood that pollutants will enter the storm drainage system because people will begin to practice "source controls." However, WWE does not know of data which indicate how effective nonstructural practices such as education are. Information of this kind is particularly important in the Fulbright Spring recharge area, because the basic Phase I recommendation is that the City, County, and Watershed Committee focus primarily on nonstructural methods to begin with for a variety of reasons.

3. There is an urgent need to establish the appropriate mixture of structural and nonstructural control measures. One of the basic findings of this Phase I report is that a mixture of structural and nonstructural BMPs is necessary and that the initial focus should be on nonstructural methods rather than on structural methods. However, pilot projects would help the study sponsors to understand how much structural control, and what kinds of structural controls, are necessary to supplement the nonstructural side of the equation.

4. This Phase I report provides a long list of *"potentially applicable"* stormwater quality BMPs. Considerations specific to Springfield will ultimately dictate which of these BMPs will work and which will not. Pilot studies would enable the sponsors to get a much better handle on both technical and nontechnical, localized "implementability" issues.

It is beyond the scope of this Phase I study to offer recommendations on the nature of pilot projects. However, at a conceptual-level, WWE has the following observations/suggestions:

1. Land developers with a "progressive/innovative" image should be encouraged to participate.

2. Incentives of some sort will need to be provided.

3. It will be essential to conduct both surface water and groundwater monitoring at the pilot sites as well as sites that "typify" existing development practices in Springfield, so as to measure the effectiveness of the water quality BMPs that are implemented. Monitoring regarding the effectiveness of the controls would be the responsibility of the City/County. Establishing monitoring programs for the pilot projects will be a difficult task and much thought will need to be devoted to this subject.

4. It will be necessary to contrast the characteristics of development sites that have accounted for stormwater quality management versus development sites that have not. This comparison should include many factors in addition to surface/groundwater quality downgradient from the site. Potential factors include, for example: maintenance regime; aesthetic appearance; impact of development scheme on potential purchasers and existing homeowners; incremental cost of stormwater quality management controls, on a unit basis; implications of structural BMPs in the neighborhoods.

7.5 SPECIFIC COMMENTS FROM INDEPENDENT REVIEWERS

As mentioned previously, comments have been elicited from Earl Shaver and Eric Livingston, based on their extensive experience in developing stormwater quality management programs. These include plans developed for areas with karstic geology very similar to that found in the Fulbright Spring recharge zone. A summary of their comments is presented in this section, and copies of their correspondence are provided in Appendix 6. It is readily apparent that these comments are similar to those already discussed, but they are included in order to reinforce critical points.

1. A *combination of structural and nonstructural strategies* will be needed to provide for effective protection of Fulbright Spring. These should include: land use controls, pollution prevention measures, public/worker education, structural BMPs, full utilization of the existing erosion and sediment control and sinkhole ordinances, effective implementation of a comprehensive stormwater management program for the basin, and adequate funding of all these efforts. Maintenance, monitoring, and enforcement are also essential.

2. On each development site, the post-development stormwater peak discharge rates should be no greater than pre-development levels for specified frequent and infrequent design storms.

3. Stormwater management should emphasize the BMP "treatment train" approach, which emphasizes the installation of a *series* of mitigation practices.

4. Minimize "directly connected impervious areas" and impervious surfaces. This is discussed further under structural BMPs.

5. Buffer zones should be required around many sinkholes and other important geologic features in the basin. The width depends on site-specific factors such as land use type and intensity, soils, slopes, etc. In addition to buffer zones, minimum setbacks should be considered. For example, stormwater systems and on-site wastewater systems are typically set back 100 to 300 feet from critical areas in Florida.

6. Minimize the amount of land which is cleared during construction. This can be accomplished through local codes by requiring a minimum area of a site to be maintained

in natural condition (i.e., Tallahassee requires 20 percent) or by requiring the careful scheduling and staging of construction. It is preferable to use both methods.

7. Purchase sensitive areas or establish conservation easements.

8. Consider pollution prevention BMPs that have proven effective. These include:

   a. Street and parking lot sweeping using vacuum sweepers.

   b. Detecting and eliminating illicit connections to the stormwater system.

   c. Proper handling, use, and disposal of fertilizers and pesticides. A preferable method is natural landscaping, promoted by demonstrations of something like "the Missouri Yard" which displays environmentally sound landscaping and maintenance.

   d. Proper handling, use, and disposal of household chemicals. Establishment of household hazardous materials recycling and waste disposal centers. Community demonstration project of recycling old paints, remixing to create "mix color paint" that is used for public or charitable purposes.

   e. Proper disposal of pet wastes—a major source of coliforms and other pathogens.

   f. Opportunities at businesses or industries:

      - Require pollution prevention plans and employee training on proper use and disposal of materials that are potentially damaging to groundwater.

      - Review of materials, especially solvents and other liquids, used in processing and emphasize replacement with less hazardous or toxic materials.

      - Proper siting, storage, and, where necessary, containment of materials. For example, loading docks, storage areas, and equipment maintenance and storage areas are areas that should be roofed to minimize exposure to

rainfall and runoff. Another example is the storage of fertilizers and pesticides at lawn and garden centers.

g. Education programs for developers, designers, engineers, and inspectors are essential.

h. To assure long-term operation and maintenance of stormwater systems, operating permits (with annual inspections and renewals) can be required. "Adopt-a-Pond" (BMP) programs can also be established to promote proper maintenance and operation of stormwater systems serving residential developments where a property owners association is the legal maintenance entity. WWE's experience strongly argues for public maintenance of drainage systems.

i. Public education programs including "Eco-Neighborhoods," "Adopt-a-Sinkhole," "Missouri Yards and Neighborhoods," storm sewer stenciling programs, booklets, videos, etc.

j. An on-site wastewater management program which conducts regular inspections of on-site systems and assures that necessary maintenance is performed.

9. Address winter road management.

a. Carefully site snow storage areas so that runoff or seepage from the snow pile doesn't harm waters and is properly treated before discharge.

b. Minimize or eliminate the use of salt (sodium chloride). Alternatives include sand, calcium magnesium acetate, calcium chloride, etc.

c. Store salt properly which means away from critical or sensitive areas, on impermeable surfaces, and under a roof.

10. Site-specific evaluation of BMPs must account for the need to maintain the basin recharge characteristics, to the extent practicable. This normally argues for infiltration, but in karst geology, any infiltrated stormwater must assuredly be clean before it enters the groundwater system. This means that special infiltration practices, including imported backfill, liners, and underdrains, will often be necessary.

11. The effectiveness of local erosion and sediment control programs should be maximized. Without this, other efforts may be for naught. A recent study noted by Shaver shows that the principal reasons for poor implementation of erosion control programs are inadequate staffing, funding, and political support.

12. Rather than a "cookbook" approach, BMPs should be selected on a site-specific basis, within broad guidelines and criteria.

13. Consider flexibility on the requirement of curbs and gutters and enclosed storm drain systems.

14. To use all of the nonstructural BMPs available, it is recommended that a geographic information system be used for the development and implementation of the watershed plan. Not only can this provide a very cost-effective manner of evaluating different land use scenarios but it can also be used to track implementation and even schedule future maintenance inspections of septic tanks or stormwater treatment systems.

15. All of these efforts rest on an adequate and permanent source of funding. The national experience indicates that a stormwater utility is the best choice. An advalorem tax on the residents of the county at large may also be effective. These programs should not rely on federal funding (except for one-time expenses), permit fees, or yearly appropriations by the local governing body.

7.6 SUMMARY/GUIDING PRINCIPLES

In summary, comprehensive watershed masterplanning, adequate funding, and education programs are the keys to developing a program that will ensure acceptable water quality levels within the Fulbright Spring/South Dry Sac River watershed. Following are some guiding principles to assist in preserving this critical resource.

1. The longer action is delayed the higher will be the associated costs to provide adequate protection of the recharge area.

2. Education should be the center of all actions related to a comprehensive program for protection.

3. Although not needed immediately, masterplanning should be considered for the recharge area and the sooner this is starter the sooner basin-wide protection can be provided.

4. Engineering and technical design guidance will be needed so that proper designs can become an integral part of local development design.

5. Local ordinances and regulations should be reviewed and revised to provide the legal measures needed for recharge protection.

6. Alternative funding sources should be examined now and measures taken to provide this funding in the near future.

7. Inaction will lead to either serious degradation of the local water resources or large increases in costs for pollution control. Time is money and the community must decide when they will be willing to provide the needed resources.

CHAPTER 8
STRUCTURAL BEST MANAGEMENT PRACTICES

8.1 INTRODUCTION

To accomplish the objective of strictly limiting spring degradation, even if the nonstructural controls described in Chapter 7 are fully implemented and prove to be effective, *structural BMPs will also be necessary.* WWE recommends that all new land development projects in the spring recharge area have, at a minimum, simple structural BMPs that specifically address water quality. The following are key components of the program for structural BMPs that should be adopted for the Fulbright Spring recharge area:

1. The "treatment train" approach to BMPs should be emphasized. Specifically, for any given new development site and even in "retrofitting" situations, it is desirable and necessary to utilize multiple BMPs in series, rather than a single BMP. For example, in a portion of the basin that will experience residential growth, it will be desirable to encourage families to strictly practice "source control" (limit fertilizer and pesticide use, do not throw chemicals down the storm drain, etc.) This should be followed by individual building lot controls, then controls that apply to the entire subdivision. Finally, regional controls (such as large, wet retention ponds) should be adopted when the City and County have adequate funds to install and maintain such facilities.

2. Although not strictly a structural BMP, every attempt should be made to minimize "directly connected impervious area" in newly developing areas. Based upon WWE's inspection of the spring recharge area, this represents a change in drainage philosophy. Nonetheless, once the approach is utilized by developers, there is little difficulty in design and implementation.

3. Particularly during the early stages of the watershed protection program, *on-site* BMPs should be favored over *regional* BMPs. As the name implies, on-site BMPs are small, relatively inexpensive and normally unsophisticated practices that are installed on individual lots or individual developments. These include incorporating vegetated depressions into the landscaping plan, grass-lined channels, vegetated buffer strips, small, dry detention ponds, "slow-flow" channels with dry or wet bottoms, etc. On-site BMPs are normally constructed by the residential, commercial, and industrial developer and their

continuing maintenance is normally the developer's responsibility. Regional BMPs, by contrast, are larger, more sophisticated, and are generally designed, constructed and maintained by local governments. Examples of regional BMPs include wet retention ponds, wetlands complexes, infiltration basins with pretreatment facilities, and the like.

The question arises as to what combination of on-site and regional BMPs is appropriate for the Fulbright Spring recharge area. WWE recommends that, in the near-term, the on-site approach be favored by the study sponsors while in the longer term it will be desirable to have regional BMPs as well in strategic locations. On-site BMPs are favored in the short-term because there is not adequate money to design, construct and maintain regional BMPs. Furthermore, stormwater quality management, which focuses on capturing, storing, and treating a small amount of runoff (probably the first 0.5 inches of runoff in the Fulbright Spring watershed) readily lends itself to on-site facilities. In the longer term, once an adequate funding source has been developed and the basin has been masterplanned, it would be desirable for the sponsors to move ahead with the construction of some regional stormwater quality management facilities. It is premature to now even speculate on how many such facilities may be necessary or where they would be required, but this should be kept in mind as a possibility.

4. The City and County should assure that on each development site, the post-development stormwater peak discharge rates are not greater than pre-development levels, for both frequent and infrequent design storms. Enforcement of this requirement will facilitate water quality objectives. A watershed-specific master drainage plan needs to be developed and followed to coordinate the implementation of detention facilities and to strategically locate regional storage/treatment systems.

5. To the extent practicable, stormwater quality treatment should be "off line" (off the main channels).

6. The City and County will need to specify a "treatment volume," during Phase II of the watershed protection plan for such facilities. For example, many communities specify a "water quality design storm," normally around 1.0 inches of rainfall. The stormwater programs in Florida, Maryland, and Delaware have all set a minimum treatment level equal to the removal of 80 percent of the average annual loading of total suspended solids (TSS), and this is an alternative approach for establishing the "treatment volume." In any

event, it should be a routine requirement for developers to capture, store and treat the defined "treatment volume."

7. Infiltration practices need to be used with great caution in the Fulbright Spring recharge area because there is such a high potential for pollutants to directly enter the groundwater system. There are many infiltration practices which may apply, however. For example, the City of Austin, Texas faces much the same constraints as Springfield does. As a result, that city has developed the widely-cited "Austin Sand Filter," which provides high levels of pollutant removal via a facility that is practical and maintainable. Generally, if infiltration practices are going to be utilized, they will require special techniques in the Fulbright recharge area, with emphasis on imported backfill, underdrains, and liners.

8. The City and County will need to encourage flexibility on the part of developers and their designers. For example, assuming that concerns of the local fire department can be satisfied, it may be feasible to reduce road widths in subdivision and to emphasize loop roads rather than cul-de-sacs.

9. WWE recommends that the City and County utilize the existing NPDES stormwater program authority to require appropriate pollution prevention plans.

10. In the process of defining SEFs in the basin, WWE has defined and prioritized pollution sources. *During the second stage of the Watershed Protection Plan (Phase II), it will be necessary to define structural BMPs that are appropriate for the key pollution sources in the basin.*

8.2 BMP ANALYSIS AND APPLICABILITY

Appendix 7 provides detailed descriptions of 14 BMPs that are potentially applicable to the Fulbright Spring recharge area. The advantages and disadvantages of the BMPs are described within the text, along with their potential applicability to the Springfield area. This review has been made utilizing information from numerous sources and parts of the country, but the critique of each is from the viewpoint of how it might be applied to this project area. We have also provided a summary numerical analysis in Table 8-1 of the strengths and weaknesses of each BMP in order to provide an objective system for decision-making.

TABLE 8-1
NUMERICAL ANALYSIS OF STRUCTURAL BEST MANAGEMENT PRACTICES

BMP	ED Dry Basin	Wet Detention Ponds	Wetlands	Filter Strips	Grassed Swales	Austin Filter	Sand Filters	Infiltration Trenches	Infiltration Basins	Porous Pavement	Oil/Grit Separator	Conv. Catch Basins	Catch Basin Inserts	Regular Detention Basins
General Applicability	3	4	3	4	3	4	4	3	3	2	1	2	1	1
Applicability as on-site BMP	4	2	2	5	5	2	2	1	1	1	3	1	1	4
Groundwater Protection	3	4	4	2	2	4	4	3	3	3	1	1	2	1
Secondary Objectives	3	4	4	3	3	4	4	3	3	3	1	1	2	1
Advantages	4	4	4	4	3	4	4	4	4	3	1	1	3	1
Disadvantages	3	3	4	3	3	3	3	2	2	2	0	0	2	0
Costs	3	3	2	5	5	3	3	2	3	3	2	3	3	3
Implement-ability	3	3	5	4	4	4	4	3	3	3	1	1	2	1
Maintenance	3	3	4	4	4	2	2	2	2	1	1	3	1	1
TOTAL	29	30	32	34	32	30	30	23	24	21	11	14	17	13

KEY: Each category is rated from 0 (least desirable) to 5 (most successful); note that a value of "0" for disadvantages means there are many disadvantages.

The numerical analysis in Table 8-1 is based on the evaluation of each BMP in the report. Although total scores for each are given, these should not be used as a "bottom-line" evaluation. There is equal weighting given to each category, and this may not be appropriate in the final planning process. Perhaps protection of groundwater quality should receive a higher weighting than cost analysis. Another option is to first rank the BMPs based on groundwater protection, and then subrank by implementability. Obviously, there are many variations.

While examining these BMPs, some caution is in order. The performance of these BMPs, particularly in terms of pollutant removal, have limited supporting data. In cases where data are found in the literature, we have made a reasonable effort to find the original research in which the data were presented. This is in order to analyze the assumptions and experimental procedures that were used to generate the data and allow us to qualify the results as necessary. Often, reported values are not from actual operating systems, but only estimates from computer models or limited testing of experimental systems. Furthermore, only general inferences about removal rates should be made, as actual removal rates will vary by the storm hydrograph characteristics, age of the system tested, and whether or not proper design and maintenance has been performed. Indeed, most reports give a wide range of pollution removal efficiencies.

A second caution should be made by repeating that structural BMPs, like unit operations in a water or wastewater treatment facility, are only part of an overall "treatment train." This is particularly important for stormwater BMPs in a karst area. Notations have been made for those practices that strictly require preceding or followup BMPs, but the statement applies generally as well. Furthermore, throughout our discussions with experts in BMP selection and design, each has emphasized the importance of proper maintenance of BMPs to insure maximum effectiveness and lifespan. The most effective of BMPs will soon become useless without proper attention to the need for routine and non-routine maintenance.

From this analysis, it is apparent that several BMP designs have limited or no applicability to the Fulbright Spring area, while others appear to have significant potential. In between, there are a number of systems which could be beneficial or ineffective depending on proper use, design, construction, and maintenance. Thus, it is not a simple matter of picking the right BMP and universally applying it. No one BMP will be universally applicable. In addition, each BMP has its own "target pollutants" for mitigation; e.g., an Austin Sand Filter may be useful for runoff from an industrial site but not for a low-density residential area. Finally, although a BMP may not be fully effective on its own, it may be indispensable in a treatment train as discussed above.

8.3 SPECIFIC OBSERVATIONS AND RECOMMENDATIONS

Some specific comments regarding these BMPs have been developed based on the information presented in this chapter as well as comments from Dr. Thomas Debo, Mr. Earl Shaver, and Mr. Eric Livingston. These are as follows:

1. Numerous structural BMPs have been identified as potential candidates for use in the Fulbright Spring Recharge Area. Extended detention dry basins, wet detention ponds, and infiltration basins (possibly with liners/underdrains to prevent direct entry to groundwater) offer good pollutant capture as well as control of peak stormwater runoff from large contributory areas. Sand filters, filter strips, grassed swales, and porous pavement can reduce runoff and remove pollutants from smaller tributary areas for on-site runoff control. Wetlands can be used in conjunction with other BMPs to provide effective peak flow control, pollutant removal, and some recharge.

2. One of the concerns in any urbanized area is the presence of organic compounds in runoff; particularly halogenated solvents, fuels, and other hazardous organics. Research in this area is minimal, but there is emerging evidence that sand filters may be effective for trapping of these compounds, and wetlands may be valuable for their filtering ability as well as their support or organisms that can metabolize these compounds. Wet ponds with extended residence times should also be valuable for these compounds.

3. Treatment should be "off-line" (off-channel) to the extent feasible. Before an appropriate treatment volume can be specified, two steps must be taken. First, a performance goal or minimum treatment goal should be established. This will be a function of the spring water quality criteria/standards that are adopted. The state stormwater programs in Florida, Maryland, and Delaware all have set a *minimum treatment level* equal to removal of 80 percent of the average annual loading of TSS. This also is the goal set in the Section 6217 Coastal Non-Point Source (NPS) Control Program BMP guidelines. During Phase II of the spring protection program, the project sponsors will need to establish whether this level of treatment is high enough to accomplish the goal of strictly minimizing impacts on spring water quality. Second, once the performance standard is determined, design criteria must be established for the various BMPs that will be used. For off-line infiltration areas, the treatment effectiveness is a function of the percent of the annual runoff volume which is diverted, retained, and infiltrated. Therefore, to establish design criteria, whether for retention or detention systems, long-term

precipitation records for the area should be statistically analyzed to develop precipitation-frequency data which can be used to develop diversion or treatment volume curves.

4. Basin-wide stormwater treatment can emphasize shallow, vegetated storage/filtration areas distributed around development sites. This is effective, inexpensive, and aesthetically pleasing.

5. Minimize "directly connected impervious areas" and impervious surfaces, generally.

   a. Assure that commercial parking requirements are appropriate for expected traffic flow.

   b. Review requirements for road widths and see if they can be reduced without jeopardizing public health or safety. One subdivision in Delaware reduced its impervious area by 20 percent by reducing the width of interior roads. The use of loop roads instead of cul-de-sacs met the concerns of fire departments.

   c. Promote the use of alternative parking lot materials such as "Geoweb" with sod or gravel, turf blocks, etc. These are especially appropriate on parking spaces that are rarely used and which are farthest from the store.

   d. Encourage the use of pervious pavement. This recommendation is made with caution. The use of pervious pavement needs to be based upon local site conditions, experience, testing, and expertise of the community's engineers and contractors. Florida has had good experiences with pervious concrete but not porous asphalt.

   e. Selectively advocate the use of swales instead of curbs and storm sewers, at least in residential areas. Swale "blocks" or raised driveway culverts should be used to retain the water within the swale and let it infiltrate. The swale must be fully vegetated, preferably with a dense grass established by sodding. This is especially needed to minimize the movement of stormwater pollutants through the soil and into the groundwater. Even in commercial parking lots, swales should be an essential part of the BMP treatment train.

f. Parking lot islands can be recessed, sodded, and landscaped, and curb cuts used can be to allow runoff to flow into these mini-retention/swale areas. These can be interconnected into a conveyance system leading to an infiltration or other stormwater BMP. Alternatively, but less preferred, a storm sewer inlet can be placed in the bottom of the mini-retention area with the inlet raised above the bottom of the area to promote settling and infiltration.

6. To assure long-term operation and maintenance of stormwater systems, operating permits (with annual inspections and renewals) can be required. "Adopt-a-Pond" (BMP) programs can also be established to promote proper maintenance and operation of stormwater systems serving residential developments where a property owners association is the legal maintenance entity. WWE's experience strongly argues for public maintenance of drainage systems.

7. A wastewater management program should conduct regular inspections of on-site systems and assure that necessary maintenance is performed.

8. Site-specific evaluation of BMPs must account for the need to maintain the basin recharge characteristics, to the extent practicable. This normally argues for infiltration, but in karst geology, any infiltrated stormwater must assuredly be clean before it enters the groundwater system. This means that special infiltration practices, including imported backfill, liners, and underdrains, will often be necessary.

9. Ponds will frequently be the practice of choice due to concern over contaminant migration to the groundwater. Pond liners (geotextile or clay) may be needed on a case-by-case basis. Also, sand filters work very well in "ultra-urban" sites. Wetlands should be viewed with caution, because at times they are nutrient exporters.

10. Rather than a "cookbook" approach, BMPs should be selected on a site-specific basis, within broad guidelines and criteria.

11. Consider flexibility on the requirement of curbs and gutters and enclosed storm drain systems.

12. All of these efforts rest on an adequate and permanent source of funding. The national experience indicates that a stormwater utility is the best choice. An advalorem tax on the

residents of the county at large may also be effective. These programs should not rely on federal funding (except for one-time expenses), permit fees, or yearly appropriations by the local governing body.

13. The strength of a particular BMP in mitigating runoff quality and quantity will be dependent on several factors:

    a. Proper design and placement of the BMP. For example, infiltration type BMPs should not be placed in soils that either drain poorly or too quickly to groundwater, or areas with high water tables.

    b. Proper maintenance and monitoring of the BMP. All of these practices require routine and non-routine maintenance and monitoring to sustain their effectiveness. Certainly, some require more care than others, but maintenance/monitoring must be included in budgeting or the BMP will likely fail.

    c. Use of a treatment train, similar to that used in municipal water treatment processes. An example would be the use of on-site filter strips followed by an infiltration trench that leads to an extended dry detention basin. Such a treatment train would provide multiple layers of pollutant removal, runoff control, and groundwater recharge.

Finally, it should be noted that the selection of BMPs is also dependent on the level of water quality protection afforded by nonstructural BMPs. It is widely held that public education, proper land use controls, landscaping techniques such as reduction of directly connected impervious area, and pollution prevention controls are extremely effective measures. Close attention to the nature of site design and layout can go a long way toward reducing pollution. For example, landscaping and terracing provide natural buffers, rainfall holding and infiltration areas. Use of low maintenance locally derived vegetation reduces the need for pesticides and fertilizer. Directing roof and driveway runoff across grassy areas provides natural filtration and infiltration. Clustering designs, zoning density limitations, critical area identification and protection and joint regional design planning can all work toward an inherent lowering of pollution levels. These techniques are discussed further under the topic of nonstructural BMPs. Through the use of these techniques, the need for expensive structural BMPs can be reduced.

This report is not intended to support the immediate design or construction of structural BMPs; instead, it is a planning tool which provides conceptual-level engineering guidance to be used in subsequent phases of a comprehensive stormwater and urban runoff management plan for the Fulbright Spring recharge area. These BMPs are simply tools used to partially mitigate the hydrological and environmental effects associated with urbanization. Other pieces of this plan include information on nonstructural BMPs, pollutant sources, sensitive environmental features, and the hydrogeologic features of the basin that impact the choice of BMPs. This is information that is also presented in this report under the scope of work for the Phase I study.

APPENDIX 1
RATIONALE AND SUPPORT FOR THE SEF IDENTIFICATION AND RANKING METHOD

APPENDIX 1
RATIONALE AND SUPPORT FOR THE SEF IDENTIFICATION AND RANKING METHODOLOGY

INTRODUCTION

The methodology selected for the identification and ranking of sensitive environmental features (SEFs) was developed by WWE to support the reconnaissance-level analyses that will be completed as a part of this contract. The identification and ranking procedure developed is also suitable for expanding SEF analysis in future phases of the comprehensive watershed planning process for the Fulbright Spring/South Dry Sac Basin. Thus, the first section of this document is intended to detail a specific procedure recommended by WWE for the completion of Task #2. This appendix is intended as a discussion document, which will provide additional detail to the Watershed Committee, and direct discussions to critical methodological issues associated with the identification and ranking methods selected by WWE.

GENERAL DEFINITION

As a starting point, it may be useful to define what WWE considers a SEF. In the Fulbright Spring watershed, a SEF will be any definable source, transport pathway, or the landscape feature eventually associated with environmentally damaging conditions. This definition recognizes that the presence of a feature, such as a swallow hole, will be of little consequence unless that feature contributes to environmental, or more specifically, water quality degradation. Sensitivity, as considered in this definition can vary as a function of basic environmental properties and processes and the real, or estimated, potential for the production of environmental degradation.

> A *property* is: a spatially defined feature, a principal characteristic of the physical, chemical, or biological environment, or an attribute of the watershed/ecological system. Example properties include soil type, a losing stream reach, location relationships between sources transport paths and landscape features, etc.
>
> A *process* is: a principal function associated with a environmental property. Processes can be described, and quantified, by physical, chemical, or biological measurements. Processes may also be an action/activity, or succession of functionally related stages identified through time and associated specifically with a feature. Example processes include erosion/sediment suspension, vegetation growth, pollutant removal/transport, etc.

The breadth of this definition allows inclusion of "areas with significance for water quality protection" and "potential problem production areas" as elements of any SEF.

With acceptance of a general definition for a SEF, it is necessary to examine how the definition can be applied in the context of the Fulbright Spring/South Dry Sac River basin, which will meet both short term objectives (activities in the present contract), and long-term objectives (future

watershed assessment and protection activities). WWE believes application of a comprehensive SEF identification and ranking procedure will require:

a) development of an organized approach to identification and measurement of environmental properties and processes associated with SEFs,

b) agreement on a rationale for inclusion or exclusion of properties or processes from consideration when examining SEFs, and

c) development of a ranking scheme to assist in prioritizing actions to protect Fulbright Spring water quality.

The organized approach proposed by WWE includes three major steps: 1) SEF identification and specification, 2) connecting SEF characteristics with critical water quality issues to develop a basis for assessing "sensitivity," and 3) developing ranking criteria for SEF categories (source, transport path, landscape feature) that will allow analysis of a "source-to-landscape feature" connection as a part of the final SEF ranking.

In the WWE approach, it is necessary to consider a range of issues as the SEF identification and ranking process proceeds. Experience has shown that critical issues are often identified if the following questions are considered:

1) are the environmental properties and processes considered in feature identification unnecessarily inclusive or exclusive (e.g. is the property or process generic or site-specific?);

2) once properties and processes are identified, what are the critical physical, chemical, and/or biological measurements that can be made to confirm effect (e.g. water quality degradation);

3) what are the critical water quality issues associated with a sensitive environmental feature;

4) are we asking the proper questions when assessing a sensitive environmental feature? (e.g. considering either a generic, or site specific analysis, is the feature well enough defined that analysis will lead to a specific management objective and a defined course of action for environmental protection), and;

5) if a question is answered, will that answer meet some criteria for acceptability, and does the answer have bearing on general project objectives (e.g. does an understanding of a feature contribute to better identification of BMPs or ordinances?).

DEVELOPING A PROCESS FOR SEF IDENTIFICATION AND RANKING

Although almost any environmental feature in the watershed is a candidate for selection as a sensitive environmental feature it is possible to limit the features evaluated based on some simple criteria. For example, a feature may be excluded from initial analysis because no measures are available to assess, and possibly even identify, the character of a feature. Further, even if a feature is amenable to measurement, the feature may have limited importance as a "sensitive" environmental feature. Clearly, measurement capacity is an important consideration in SEF identification and ranking. In the following discussion, the identification of SEFs will be considered in light of our present capacity for physical, chemical, and/or biological measurement and our capability for translation of those measurements into meaningful estimates of environmental consequence.

WWE recognizes that in addition to measurement, the process for identification and ranking of SEFs is also dependent on identification of how the properties or processes associated affect use. This "use designation" sets the stage for definition of criteria, specification of acceptable contaminant levels, and identification of needed watershed management or treatment process types, which will meet environmental quality requirements. To reduce the possibility that an important environmental feature might be overlooked because its relationship in a watershed setting is unknown or poorly defined, WWE recommends that the following issues be considered in environmental feature identification and ranking.

Issue #1 Properties and processes of any environmental feature selected for initial SEF determination must be well defined and amenable to measurement using readily available techniques.

a) any measure or metric of a property or process must be quantitative, if qualitative the measure must meet QA/QC standards,

b) measures should respond in predictable fashion to change (e.g. stormwater influence),

c) the measure must be flexible to accommodate application to either source, transport, or landscape feature functions,

Issue #2 If the properties and processes of an environmental feature are unknown and undefined, SEF determination will be largely qualitative.

a) QA/QC principles may not apply - primary QA/QC procedure will be associated with feature documentation,

b) response will be unpredictable,

c) assessments will be subjective, largely based on physical distance from SEFs.

Issue #3 Determination of sensitivity of an environmental feature can be determined quantitatively, but full characterization of feature sensitivity is dependent on a use designation.

a) the primary use assumed in SEF identification and ranking is protection of a drinking water supply (because Fulbright Spring basin water will be treated prior to use, source water quality requirements are associated with treatment capability rather than direct use criteria), and

b) sensitivity can be related to a change of conditions that will require more expensive, or new treatment technology.

Addressing these issues can be directed by considering Table 1. In Table 1 SEF categories are associated with representative environmental features (properties), which are then related to possible criteria for ranking (typical measurements that might be made to define a feature).

Following guidance provided by the questions asked above, and considering appropriateness of any property or process in a feature identification and ranking process, WWE suggests that the process for sensitive feature identification first consider a general identification/specification step, then connect identified features with critical water quality issues, and finally consider a ranking scheme based on critical environmental protection requirements, and the practicality and feasibility of control options. Details of those steps follow:

TABLE 1
CATEGORIES OF ENVIRONMENTAL FEATURES AND POSSIBLE CRITERIA USED FOR RANKING OF SEFS

SEF Category	Representative Environmental Features	Possible Criteria for Ranking
SOURCES	**Isolated/Diffuse** • septic tanks • non-point sources **Small Areas** • buried tanks • small businesses/farms • homes **Large Areas** • industrial parks • subdivisions • interstate highways • railroads • golf courses • irrigation systems • large farms • sewer systems • quarries • landfills	• Area • Pollutant/contaminant present • Spill potential • Monitoring data • Loading • Quantity of stormwater runoff • Frequency of runoff • Probability of contact with stormwater • Potential for changing basin hydrology • Single vs. cumulative effects
TRANSPORT PATHS	• Natural surface channels • Man-modified surface channels • Underground channels • Rundowns/constructed channels • Detention basins/ stormwater controls	• Natural barriers to flow • Length • Flow capacity • Time of travel • Connectivity • Pollutant removal capability • Proximity to sources of concern • Connection to Fulbright Spring • Direct/indirect
LANDSCAPE FEATURES	• Geologic Features fracture zones sinkholes/depressions swallowholes losing stream reaches • Soils w/ high infiltration rates • Areas w/ high groundwater • Lakes/reservoirs • Known recharge areas	• Permanent/temporary • Connectivity • Proximity to sources of concern • Potential for pollutant removal • Access/Public Safety

Step #1 - SEF identification/specification

1. Identify SEF location

   locate SEF on base map
   develop location descriptor
   define area
   relate to surroundings (distance from other SEFs, slope, etc)

2. Identify SEF type[1]

   - source
     - continuous/intermittent
     - pollution potential
     - frequency of pollution
     - effective pollution production area
   - transport
     - transport path defined/undefined
     - direct/indirect path to landscape feature
     - time of travel
   - landscape feature
     - permanent/temporary
     - expected connectivity w/ sources & transport paths
     - access - public safety risk

3. Specify SEF characteristics (primary emphasis connectivity and frequency)

   relate potential sources, transport paths and landscape features to specify SEF connectivity
   - define spatial factors --> distance between source and landscape feature
   - define temporal factors --> frequency of occurrence (continuous flow, stormwater driven, spill, or infrequent)

Step 2 - Connect SEF character with critical water quality issues

1. Identify critical water quality issues associated with SEF (analysis will first determine water quality issues associated with a single feature or category within an SEF)

   - presence of pollutants/contaminants

[1]Consider whether subject to change with development - identification will be based on qualitative analysis consistent with a reconnaissance-level assessment

- expected loading
- expected consequence

  human health consequence (criteria exceedence evaluation)
  environmental consequence
  possible direct toxicity --> short term receiving system effect
  possible indirect toxicity --> long term watershed-level effects
  physical nuisance production (associated public safety issues)

2. Identify critical water quality issues associated with readily defined SEF connections

- perform simple addition of loading for connected features and/or related SEF categories to develop "total" impact assessment
- the primary focus of this analysis will be identification of connections to Fulbright Spring and determination of frequency of occurrence of any event that may degrade water quality

Step 3 - Rank SEFs based on expected risk to water quality degradation

- For each category of SEF determine a potential for water quality degradation and score on a scale of 1 to 5 (where 1 = low and 5 = high potential):

SOURCE

0 - No known pollutants[2] present
1 - Pollutants present; no obvious loading
2 - Pollutants present; loads low
3 - Pollutants present; loads moderate
4 - Contaminants[3] present; loading infrequent; low stormwater and/or spill potential
5 - Contaminants present; loading frequent or continuous; high stormwater and/or spill potential

TRANSPORT PATH

Transport paths have been divided to include natural or artificial channels and overland flow patterns associated with landscape features with internal drainage:

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[2]Pollutants are natural or man-made substances that typically do not produce direct toxicity, including sediment, nutrients, urban runoff, and other non-point related sources.

[3]Contaminants are typically man-made or processed natural substances that can produce direct toxicity. Contaminants include toxic organic compounds, toxic metals, and other compounds typically associated with point sources. Excess loading of a pollutant, which produces direct toxicity, will be considered a contaminant.

Channels

0 - No defined channel or transport path
1 - Poorly defined channel; flow intermittent (mainly in storm events)
2 - Defined channel; flow intermittent
3 - Defined channel; continuous flow; long distance (> 5 mi.) from identified landscape feature
4 - Defined channel; continuous flow; moderate distance (1 - 5 mi) from identified landscape feature
5 - Defined channel; continuous flow; short distance (< 1 mi) from identified landscape feature

Overland flow/Internal drainage

1 - Sheet flow over natural/undisturbed ground
2 - Sheet flow over disturbed ground; vegetation present; path generally long
3 - Sheet flow over disturbed ground; impervious material common; path short
4 - Flow directed through channel or conduit; some natural barriers to flow exist; path generally long (> 2000 ft)
5 - Flow directed through channel or conduit; no impediment to flow; path generally short (< 2000 ft)

LANDSCAPE FEATURES

0 - Landscape feature is isolated with no known connection to Fulbright Spring
1 - Landscape feature with unknown/uncertain connection to Fulbright Spring
2 - Landscape feature suspected of having an indirect connection to Fulbright Spring; connection long or natural impediments to flow exist
3 - Landscape feature known to have an indirect connection to Fulbright Spring
4 - Landscape feature suspected of having a direct connection to Fulbright Spring; connection may be long or natural impediments to flow exist
5 - Landscape feature is known to have a direct connection to Fulbright Spring

Note: ranking will generally identify SEFs with: a) a high risk of water quality degradation identifying a need for remedial action, b) an expected, but undetermined risk of water quality degradation calling for further study and possible BMP application, or c) no or low expected risk calling for a low priority for further study and management action. This information has been generated in tabular form as shown in Table 5-2. Before any specific SEF findings are presented or discussed, however, a more refined application of the procedures will be required.

Q/A AND Q/C ISSUES

An inherent component of any procedure to identify sensitive environmental features is the need for an effective quality assurance and quality control program. Although the procedure recommended - Study Design Assurance (SDA) was developed for monitoring and assessment

programs, the principles and practices needed for SDA are applicable to the Fulbright Spring watershed. The SDA process outlined in Table 2 requires explicit identification of program, management and environmental objectives, and tasks. A program objective is a goal to be accomplished by the activity. A management objective is a goal that requires making a decision addressing actions to be taken in the environment as a result of information developed from quantifiable Audit objectives. An environmental objective is a quantifiable, non-judgmental goal that relies on the collection and interpretation of data. Audit objectives identify as precisely as possible the types, qualities and quantities of data needed, the methods of data analysis to be used, and the margins of error that can be tolerated. Audit objectives are supported by tasks, which are the data collection, analysis, and interpretation activities whose successful completion allows accomplishment of environmental objectives. The SDA process therefore determines in advance the database needed to address the various goals; data requirements are recognized as setting limits on attainment of environmental goals. WWE feels that by application of SDA principles, it will be possible to incorporate Watershed Committee input in the sensitive environmental feature selection process to optimize the work effort and produce a product that will provide the foundation for Tasks 3-5.

TABLE 2
STEPS IN THE STUDY DESIGN ASSURANCE PROCESS

Step	Activity
1.	Specify audit objectives: phrase objectives in terms relevant to a better understanding of the elements within the environment (and their dynamics).
2.	Determine the criteria appropriate to the measurement of those objectives.
3.	Develop data requirements: specify the quality and quantity of data needed to know as much as possible about the selected criteria.
4.	Display optimum or theoretical database: establish the program data requirements as a theoretical database.
5.	Recycle: develop attainable database recognizing program limitations. Identify that portion of the database expected to result from state-of-the-art monitoring.
6.	Compare audit and monitoring databases: set objectives for improving existing databases.

APPENDIX 2
SELECTED TEXT FROM THE COLORADO CODE OF REGULATIONS 5 CCR 1002-8

APPENDIX 2
SELECTED TEXT FROM THE COLORADO CODE OF REGULATIONS
5 CCR 1002-8

The following are excerpts taken from the Colorado Code of Regulations, 5CCR1002-8 (3.11.9) through (3.11.12)

3.11.9 STATEMENT OF BASIS AND PURPOSE

Statement of Basis and Purpose for adopting the Regulations entitled : "The Basic Standards for Ground Waters". In accordance with 24-4-103(4), CRS (1982 and 1985 Supp.), the Commission adopts this Statement of Basis and Purpose.

PURPOSE

"The Basic Standards for Ground Waters" establishes a system of classifications (classes) for determining the appropriate degree of protection (standards) necessary to maintain beneficial uses of ground waters. These standards and classes are intended to complement regulations 3.1.0, "The Basic Standards and Methodologies" which are primarily applicable to surface waters. Together, regulations 3.1.0 and 3.11.0 protect all state waters as defined in Section 25-8-203, CRS (1982). Separate regulations for surface and ground waters are appropriate, because the surface water classification system is not easily adopted to ground waters.

These regulations are the first step in developing a comprehensive, statewide ground water protection program. The complete program will include control regulations which will enforce the water quality standards. These additional regulations may include amending the current CDPS permit regulations and adopting activity-specific control regulations.

PUBLIC INPUT AND COMMISSION GOAL

The Commission and Division appointed an Ad Hoc Ground Water Advisory Committee in 1982. The Committee represented the various entities who would be most affected by a ground water protection program. On May 15, 1984, the Committee recommended, and the Colorado Water Quality Control Commission adopted, the following statement pertaining to ground water protection:

> "The goal of the Water Quality Control Commission is to provide maximum beneficial use of ground water resources, while assuring the safety of the users by preventing or controlling those activities which have the potential to impair existing or future beneficial uses of ground water or to adversely affect the public health. The necessary program is to be instituted in a manner that is consistent with and complementary to the provisions of the Colorado Water Quality Control Act."

This Basic Standards Regulation for ground water, which is adopted after exhaustive public rulemaking hearings, is consistent with this goal. The focus of the Basic Standards Regulation for ground water is the identification of ground water use or uses and the quality level to be maintained to assure its usefulness. This is a framework around which existing and future licensing and permitting regulations revolve in authorizing, conditioning, limiting and denying activities which could impair existing or future beneficial uses of ground water.

DISCUSSION OF REGULATIONS

Classification System

The classification system is a framework of uses of ground water which are to be assigned on a site-specific basis by the Commission so that standards for chemical pollutants can be assigned at levels necessary to protect the use.

A five (5) class system was developed for these regulations. This system is based on existing and potential future uses and actual water quality data.

1. Domestic Use - Quality
2. Agricultural Use - Quality
3. Surface Water Quality Protection
4. Potentially Usable Quality
5. Limited Use and Quality

GROUND WATER QUALITY STANDARDS

The promulgated Water Quality Standards include narrative and numeric standards.

NARRATIVE STANDARDS

The narrative standards consider all man-induced alterations of ground water. Since the Commission cannot, and will not, control the withdrawal and use of ground water, the narrative standards are designed to protect all potential uses of the waters. The narrative standards prohibit the introduction of non-natural chemicals where best available information indicates a potential threat to the public health, safety, or welfare.

The Colorado Primary Drinking Water Regulations (CPDWR) do not include MCLs (maximum contaminant levels) for many chemicals such as dioxin, TCE, and EDB. There are often health advisories and other scientific studies indicating that a specific chemical is carcinogenic, mutagenic, toxic, or poses a danger to public health, safety, or welfare. The Commission will have the ability to make a specific determination of a limit for that constituent in ground water. This section allows the Commission to make such a determination in the absence of an MCL for the chemical. The toxic and hazardous pollutant lists developed pursuant to sections 301 (a)(1) and 311 (b)(2)(A) of the federal Clean Water Act and contaminants (pollutants) that have had an

EPA Health Advisory developed for them will be used as a basis for determining what specific compounds will be included.

NUMERIC STANDARDS

The numeric standards are contained in Tables 1, 2, 3, and 4. These standards apply to classified ground water. The majority of the numeric standards listed in Table 1 are maximum contaminant levels (MCLs) for public drinking water supplies, as established by the National Primary Drinking Water Regulations. The remainder are derived from the Colorado Basic Surface Water Standards. These human health levels are set to protect the public from acute poisoning and from long-term "chronic" effects. The MCLs are also contained in the CPDWR. The limits for radioactive constituents; Cesium, Plutonium, Thorium and Tritium are those which would limit human exposure to four (4) millirems/year. Table 1 will be expanded as MCLs for additional parameters are developed under the National Primary Drinking Water Regulations. The numeric standards listed in Table 1 are applicable to ground waters classified "Domestic Use-Quality".

Table 2 contains additional numeric standards for "Domestic Use - Quality" ground waters. Much debate and discussion revolved around the need for these standards. These parameters are the National Secondary Drinking Water Standards and are instituted to maintain a ground water as a drinking water source requiring very little treatment. In the judgement of the USEPA Administrator, these limits are a requisite to protect the public welfare.

Contaminants (pollutants) contained in Table 2 are those which may adversely affect the aesthetic quality of a drinking water such as taste, odor, color, and appearance and which thereby may deter public acceptance of and confidence in that ground water source as a drinking water supply.

Numeric standards meant to protect a water source for agricultural uses are listed in Table 3. Table 3 numeric values were developed through Commission reviews of Water Quality Criteria in 1972, EPA/8/73/033 (March 1973). The value of the molybdenum was developed from information provided by AMAX and the Cottor Corporation. These values are set at levels to protect livestock and crops. All "Agricultural Use - Quality" ground waters must meet these standards when implemented by any agency.

Much public input and debate revolved around Table 4, "TDS Water quality Standards." Some parties wanted less or no degradation of ground water, while other parties felt that more was warranted. The division proposed this version which allows for limited degradation.

The TDS numeric standard is implemented on a sliding scale and is applicable to all classes of ground water, except "Domestic Use -- Quality" and "Limited Use and Quality" ground waters. TDS Table 4 values are applicable to "Agricultural Use - Quality", "Surface Water Quality Protection" and "Potentially Usable Quality" ground waters, because these three classes are not subject to Table 2 for sulfates and chlorides; a TDS limitation for these three classes assumes some level of anti-degradation.

By maintaining a TDS concentration within a range, an existing or potential use should not be impacted. The sliding scale allows for a twenty-five percent increase for all ground waters with a background TDS concentration greater than 500 mg/l. If the background concentration is less than 400 mg/l then the maximum allowable concentration of TDS is 500 mg/l. This value is the secondary drinking water standards and is instituted to maintain a high quality water. Total dissolved solids concentrations of less than 500 mg/l are not expected to impair any ground water use. The twenty-five percent allowable incremental increase for waters with a background between 500 and 10,000 mg/l would afford a greater degree of protection to ground water with lower TDS concentrations. Ground waters with TDS concentrations greater than 10,000 mg/l would not have a numeric limit.

Evidence has been submitted that on a site-specific basis some ground waters have become substantially contaminated with organic pollutants, e.g. as a result of past disposal practices. Although contamination is widespread, the Commission believes that the best policy option is to adopt numerical standards now, to help assure that these pollutants do not become a more widespread problem.

The organic chemicals for which standards are being adopted generally are not naturally occurring water quality constituents. Therefore, the Commission has determined that a statewide approach to adoption of water quality standards for these substances is the most efficient and appropriate means of assuring human health and environmental protection in a timely manner. Where there may be naturally occurring levels of some specific pollutant for which standards are adopted, or where other site-specific factors warrant, the Commission has preserved the flexibility to adopt alternative, site-specific standards, as discussed further below.

In addition to the adoption of the new organic pollutant standards, the Commission also adopted new ground water quality standards for a limited list of radioactive materials. These standards, are identical to those which have been and will continue in place for surface waters. The Commission rejected a proposal to adopt a new numerical uranium standard for ground water at this time, because the Commission believes that this issue warrants more site-specific analysis prior to such action. For example, the consistency with established surface water quality standards for uranium in several basins needs to be more fully considered.

C. BASIS FOR SPECIFIC STANDARDS (note revisions under next heading)

A wide range of approaches to setting standards for the organic pollutants were considered during the course of this proceeding. These ranged from setting "zero" standards for some pollutants (carcinogens), to setting standards only for chemicals for which maximum contaminant levels (MCLs) have been adopted, to setting standards based on practical quantitation limits (PQLs).

The standards adopted have been established as interim rather than permanent standards principally because it is clear to the Commission that the development of appropriate numerical criteria to protect various beneficial uses from organic pollutant impacts is a rapidly evolving area that is still very much in flux. For example, there are currently significant differences among the various criteria, advisories, and maximum contaminant levels available for a number of specific

pollutants. As new information becomes available and potential conflicts among the various numerical levels are resolved, it may be appropriate in specific instances in the future to adopt permanent standards either more or less stringent than the interim standards being established at this time. However, given the importance of controlling toxic pollutants in the environment, the Commission believes that it is necessary to move forward with the adoption of interim statewide standards at this time, and that the interim standards adopted are reasonable based on the best currently available information.

The organic pollutant standards have been divided into two categories--Table A for carcinogens and Table B for non-carcinogens . For non-carcinogens, the interim standards are based on MCLs, or lifetime exposure levels derived from the "reference dose" for constituents for which no MCLs have been adopted. Non-MCL standards generally are based on EPA health advisories or integrated risk information system (IRIS) data. The Commission has determined that this is the best information currently available as to the appropriate criteria for protection of human health for non-carcinogens.

For the Table A carcinogens, the interim standards are again based on MCLs for constituents for which these limits have been developed. For non-MCLs, standards based on the 1×10^{-6} risk level have been adopted. Recognizing that there is no scientifically "correct" risk level, the Commission has selected this level as a matter of policy, because it believes this is an appropriately conservative and protective level for human health risks.

To determine which specific pollutants to list on Table A, any particular compound was considered to be carcinogenic if it has been classified by EPA as either a Group A (known human carcinogen) or Group B (probable human carcinogen) compound. Compounds classified as Group C (possible human carcinogen), Group D (information inadequate to assess), or Group E (not anticipated to be a carcinogen), were treated as non-carcinogenic and listed on Table B. A few specific compounds classified by EPA as Group B/C were considered carcinogens and included in Table A.

The Commission has incorporated several elements into these amendments in an effort to make them as economically reasonable as possible, consistent with providing adequate protection of human health and the environment. Examples of these elements include:

1. Use of MCLs, which are set at levels that take technological feasibility into account, as standards for any pollutants for which these levels have been established;

2. Reliance on accepted detection levels as compliance thresholds where the actual standards are more stringent;

3. Establishment of more lenient points of compliance for situations with existing contamination;

4. Explicit deference to points of compliance established by certain state "implementing agencies;"

5. Provisions for adoption of site-specific standards and site-specific points of compliance to apply in lieu of the statewide provisions where appropriate; and

6. Explicit deference to certain federal regulatory programs which may apply different standards.

STATEWIDE NUMERICAL STANDARDS

1. Organic Chemicals.

In 1989, the Commission adopted certain interim organic pollution standards, applicable to ground water statewide. Several revisions and additions to those interim Standards are now being adopted. In general, the primary purpose of these changes is to provide a more thorough system to assure protection of Colorado's water resources with respect to potential adverse impacts from organic chemicals. One change adopted is to combine previous Tables A and B into a single consolidated Table A. The Commission believes that this format will be easier to read, and helps to assure elimination of potential inconsistencies between the separate tables.

a. Risk-based Water Supply Standards.

When the Commission adopted interim organic chemical standards in 1989, the Commission adopted standards based on maximum contaminant levels (MCLs) for all pollutants for which MCLs had been established under the Safe Drinking Water Act. The Commission has now reevaluated this policy and adopted health-based standards for these constituents instead of standards equal to the MCLs, whenever health-based criteria are available. Several considerations have led to this new approach.

The vast majority of the standards adopted in 1989 were already set equal to health-based criteria. MCLs generally are more lenient than health-based criteria and have been developed taking into account laboratory detection limits and the economic ability of water suppliers to treat for removal of these constituents. The Commission already has attempted to temper the application of stringent health-based standards for non-MCLs organic pollutants by providing for the application of the practical quantitation limits (PQL) concept in determining compliance with the standards. Any dilution present prior to the point of compliance would further temper the application of these standards. Therefore, the Commission has determined that it is a more appropriate policy to base these water quality standards on health-based criteria, rather than MCLs. Revisions have been made to the standards, as now contained in the consolidated Table A.

b. Other Revisions.

Standards for a number of additional organic chemicals have been added to the Basic Standards for Organic Chemicals Table in the Basic Standards and Methodologies for Surface Water to help complete Colorado's compliance with section 303(c)(2)(B) of the federal Clean Water Act. The chemicals added are ones listed as priority toxic pollutants, and for which EPA has developed

human health or aquatic life criteria under the Clean Water Act. The same additions have been made to the revised Table A in this regulation, for consistency between ground and surface water standards for organic chemicals.

The Commission decided not to include in the consolidated Table standards for total trihalomethanes or for polynuclear aromatic hydrocarbons (PAHs) as a class. The Commission believes that it is more practical to regulate individual chemicals in these groups. Some evidence was submitted indicating that not all PAHs should have the same standard. For now the Commission has adopted these standards based on the available EPA criteria, although if more specific evidence on this issue is brought to the Commission in the future, revisions can be considered.

The following are excerpts taken from the Colorado Code of Regulations, 5CCR1002-8 (3.12.5) through (3.12.12)

3.12.5 INTERIM NARRATIVE STANDARD

(1) The "Interim Narrative Standard" in 3.12.5 (2) (a) below is applicable to all unconfined groundwater in the following specified areas:

(a) The Lower South Platte River Basin Alluvium and Terrace Gravel System...

(b) The Arkansas River Basin Alluvium and Terrace Gravel System...

(c) The San Luis Valley Aquifer System...

(d) High Plains Aquifer System...

(e) Denver Basin Aquifer System...

(2) (a) Until such time as use classifications and numerical standards are adopted for the ground water in this area, and subject to the provisions of subsection (b) below, ground water quality shall be maintained for each parameter at whichever of the following levels is less restrictive:

(i) existing ambient quality as of October 30, 1991, or
(ii) that quality which meets the most stringent criteria set forth in Tables 1 through 4 of "The Basic Standards for Ground Water."

3.12.11

BASIS AND PURPOSE

A. Overview

... The new alternative proposal provides an interim narrative standard for protection of existing ground water quality on a regional basis, to be supplemented in the near term with site-specific rulemaking hearings to adopt standards and classifications for wellhead protection areas of public water supply systems and for other areas of significant interest...Over time, the experience gained through initial program implementation, the additional knowledge acquired through increasingly better data, and further examination of the ground water quality improvement issue may indicate that other approaches to ground water quality classifications and standards should be considered.

B. Interim Narrative Standard

1. Summary

The purpose and effect of the interim standard is to assure that: (1) in clean areas, quality adequate to protect all potential uses is preserved; and (2) in contaminated areas, quality is not allowed to get any worse. This interim standard defines the protection provided unless and until overridden by use classifications and numerical standards adopted at a later date, the major issue left open by the interim standard is the determination as to what level of remediation may be appropriate in the variety of circumstances where existing quality does not meet table value standards.

As addressed in subsection 3.12.5(2)(b), this interim narrative standard is not intended to discourage improvement of water quality or indicate that existing quality is adequate where contamination exists. Rather, the approach recommended reflects a decision that the determination of potential remediation requirements in the wide range of circumstances potentially at issue--e.g. agricultural use impacts, CERCLA sites, naturally elevated pollutants--would be more appropriately addressed in separate proceedings or separate forums. Subsection (2)(b) states an ambitious long-term cleanup goal. Neither this goal or the interim narrative standard are intended to prejudice the outcome of any subsequent classification and numerical standard-setting proceedings. In any such hearing, classifications and standards would be considered in accordance with the Commission's statutory and regulatory authority.

3.12.12

A. Overview

In accordance with the directive issued in the Statement of Basis and Purpose in the May 1991 hearing, the Commission has decided to proceed with classification of the specified areas surrounding 10 of the 20 largest community ground water systems in the state for domestic use-quality and agricultural use-quality, and to assign the ground water standards found in Table 1-4 of the "Basic Standards for Ground Water" to these areas. This action was taken to provide needed water quality protection for public drinking water supplies, it was not intended to impose significant changes or additional restrictions on ground water users.

B. Site-Specific Classification and Standards Setting of the Specified Areas Surrounding 10 of the State's Largest Ground Water Systems

The Commission determined that the Division's proposal to classify the ground waters underlying the specified areas surrounding 10 of the state's 20 largest public ground water systems for domestic use-quality and agricultural-use quality, and to assign the water quality standards included in Tables 1-4 of the "Basic Standards for Ground Water" 3.11.0 (5 CCR 1002-8) was reasonable and consistent with the Commission's responsibility to protect ground water quality for beneficial use.

Site-specific classification of the specified areas required information on the wells and the aquifer to develop a computer-generated model that delineates an area around the wells or wellfields. The information needed was furnished by the public water suppliers. The water found in the specified areas most directly influences the drinking water or agricultural wells, and therefore needs to meet the domestic use and/or agricultural use quality standards. This action, in combination with the assignment of the ground water standards, helps to ensure a safe, potable water supply.

The decision to add the agricultural use-quality classification was based on information that irrigation and stock watering wells were located and permitted within the specified areas. Therefore, it seemed important to protect the agricultural use through application of the agricultural table values as well as with those for potable use protection. It is anticipated that this action will provide protection of the ground water source, but will not alter or change the regulatory requirements of the Safe Drinking Water Act (SDWA).

The specified areas to be protected were determined through the use of a modular, semi-analytical ground water flow model developed for the U.S. EPA Office of Ground Water Protection for use in the wellhead protection program. Referred to as the WHPA (Wellhead Protection Area) 2.0 model, its principal application has been to delineate wellhead protection areas around public ground water systems. The term wellhead protection area refers to the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach the well or wellfield.

APPENDIX 3
MISSOURI WATER QUALITY STANDARDS

Rescinded: Filed Oct. 16, 1979, effective July 11, 1980. Readopted: Filed Feb. 4, 1980, effective July 11, 1980. Rescinded and readopted: Filed Nov. 10, 1982, effective May 12, 1983. Amended: Filed Sept. 11, 1984, effective March 12, 1985. Amended: Filed July 25, 1985, effective Dec. 26, 1985. Amended: Filed Feb. 1, 1988, effective June 13, 1988. Amended: Filed Sept. 13, 1988, effective Feb. 14, 1989. Amended: Filed July 15, 1991, effective Jan. 13, 1992. Amended: Filed Sept. 2, 1993, effective May 9, 1994.

**Original authority 1972, amended 1973, 1987.*

10 CSR 20-7.020 Effluent Regulations
(Rescinded July 11, 1980)

10 CSR 20-7.030 Water Quality Standards
(Rescinded December 11, 1977)

10 CSR 20-7.031 Water Quality Standards

PURPOSE: This rule identifies beneficial uses of waters of the state, criteria to protect those uses and defines the antidegradation policy. It is developed in response to the Missouri Clean Water Law and the federal Clean Water Act, Section 303(c)(1) and (2), which requires that state water quality standards be reviewed at least once every three years. These revisions are pursuant to the national goal of protection of fish, shellfish and wildlife and recreation in and on the water as outlined in Section 101(a)(2) of the Act.

Editor's Note: The secretary of state has determined that the publication of this rule in its entirety would be unduly cumbersome or expensive. The entire text of the material referenced has been filed with the secretary of state. This material may be found at the Office of the Secretary of State or at the headquarters of the agency and is available to any interested person at a cost established by state law.

(1) Definitions.

(A) Acute toxicity—Conditions producing adverse effects or lethality on aquatic life following short-term exposure. The acute criteria in Tables A and B are maximum concentrations which protect against acutely toxic conditions. Acute toxicity is also indicated by exceedence of whole-effluent toxicity (WET) test conditions of paragraph (3)(I)2. For substances not listed in Table A or B, 0.3 of the median lethal concentration, or the no observed acute effect concentration for representative species, may be used to determine absence of acute toxicity.

(B) Aquifer—A subsurface water-bearing bed or stratum which stores or transmits water in recoverable quantities that is currently being used or could be used as a water source for private or public use. It does not include water in the vadose zone.

(C) Beneficial water uses. Beneficial uses (1)(C)1.—11. of classified waters are identified in Tables G and H. Beneficial uses (1)(C)12.—15. of classified waters must be determined on a site-by-site basis and are therefore not listed in Tables G and H.

1. Irrigation—Application of water to cropland or directly to plants that may be used for human or livestock consumption. Occasional supplemental irrigation, rather than continuous irrigation, is assumed.

2. Livestock and wildlife watering—Maintenance of conditions to support health in livestock and wildlife.

3. Cold-water fishery—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a naturally reproducing or stocked trout fishery and other naturally reproducing populations of recreationally important fish species.

4. Cool-water fishery—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a sensitive, high-quality sport fishery (including smallmouth bass and rock bass) and other naturally reproducing populations of recreationally important fish species.

5. Protection of aquatic life (General warm-water fishery)—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a wide variety of warm-water biota, including naturally reproducing populations of recreationally important fish species. This includes all Ozark Class C and P streams, all streams with seven (7)-day Q_{10} low flows of more than one-tenth cubic feet per second (0.1 cfs), all P1 streams and all classified lakes. However, individual Ozark Class C streams may be determined to be limited warm-water fisheries on the basis of limited habitat, losing-stream classification, land-use characteristics or faunal studies which demonstrate a lack of recreationally important fish species.

6. Protection of aquatic life (Limited warm-water fishery)—Waters in which natural water quality and/or habitat conditions prevent the maintenance of naturally reproducing populations of recreationally important fish species. This includes non-Ozark Class C streams and non-Ozark Class P streams with seven (7)-day Q_{10} low flows equal to or less than 0.1 cfs and Ozark Class C streams with the characteristics outlined in paragraph (1)(C)5.

7. Human health protection (Fish consumption and secondary contact recreation)—Criteria to protect this use are based on the assumption of an average amount of fish consumed on a long-term basis. Protection of this use includes compliance with Federal Drug Administration (FDA) limits for fish tissue, maximum water concentrations corresponding to the 10^{-6} cancer risk level and other human health fish consumption criteria. Secondary contact recreation assumes limited physical contact with the water without likelihood of water ingestion.

8. Whole-body-contact recreation—Activities in which there is direct human contact with the raw surface water to the point of complete body submergence. The raw water may be ingested accidentally and certain sensitive body organs, such as the eyes, ears and the nose, will be exposed to the water. Although the water may be ingested accidentally, it is not intended to be used as a potable supply unless acceptable treatment is applied. Water so designated is intended to be used for swimming, water skiing or skin diving.

9. Boating and canoeing—Activities in which limited contact with water is assumed.

10. Drinking water supply—Maintenance of a raw water supply which will yield potable water after treatment by public water treatment facilities.

11. Industrial process water and industrial cooling water—Water to support various industrial uses; since quality needs will vary by industry, no specific criteria are set in these standards.

12. Storm- and flood-water storage and attenuation—Waters which serve as overflow and storage areas during flood or storm events slowly release water to downstream areas, thus lowering flood peaks and associated damage to life and property.

13. Habitat for resident and migratory wildlife species, including rare and endangered species—Waters that provide essential breeding, nesting, feeding and predator escape habitats for wildlife including waterfowl, birds, mammals, fish, amphibians and reptiles.

14. Recreational, cultural, educational, scientific and natural aesthetic values and uses—Waters that serve as recreational sites for fishing, hunting and observing wildlife;

waters of historic or archeological significance; waters which provide great diversity for nature observation, educational opportunities and scientific study.

15. Hydrologic cycle maintenance—Waters hydrologically connected to rivers and streams serve to maintain flow conditions during periods of drought. Waters that are connected hydrologically to the groundwater system recharge groundwater supplies and assume an important local or regional role in maintaining groundwater levels.

(D) Biocriteria. Numeric values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting waters that have been designated for aquatic-life protection.

(E) Chronic toxicity—Conditions producing adverse effects on aquatic life or wildlife following long-term exposure but having no readily observable effect over a short time period. Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four (4)-day averages. Chronic toxicity is also indicated by exceedence of WET test conditions of subsection (4)(P). For substances not listed in Table A or B, commonly used endpoints such as the no-observed effect concentration or inhibition concentration of representative species may be used to demonstrate absence of toxicity.

(F) Classified waters—All waters listed as L1, L2 and L3 in Table G and P, P1 and C in Table H. During normal flow periods, some rivers back water into tributaries which are not otherwise classified. These permanent backwater areas are considered to have the same classification as the water body into which the tributary flows.

1. Class L1—Lakes used primarily for public drinking water supply.

2. Class L2—Major reservoirs.

3. Class L3—Other lakes which are waters of the state. These include both public and private lakes. For effluent regulation purposes, publicly owned L3 lakes are those for which a substantial portion of the surrounding lands are publicly owned or managed.

4. Class P—Streams that maintain permanent flow even in drought periods.

5. Class P1—Standing-water reaches of Class P streams.

6. Class C—Streams that may cease flow in dry periods but maintain permanent pools which support aquatic life.

7. Class W—Wetlands that are waters of the state that meet the criteria in the *Corps of Engineers Wetlands Delineation Manual* (January 1987), and subsequent federal revisions. Class W waters do not include wetlands that are artificially created on dry land and maintained for the treatment of mine drainage, stormwater control, drainage associated with road construction, or industrial, municipal or agricultural waste. Class W determination on any specific site shall be consistent with federal law.

(G) Ecoregion. A major region within the state which contains waters with similar geological, hydrological, chemical and biological characteristics.

(H) Epilimnion—Zone of atmospheric mixing in a thermostratified lake.

(I) Fecal coliform bacteria—A group of bacteria originating in intestines of warm-blooded animals which indicates the possible presence of pathogenic organisms in water.

(J) Hypolimnion—Zone beneath the zone of atmospheric mixing in a thermostratified lake.

(K) Lethal concentration $_{50}$ (LC_{50})—Concentration of a toxicant which would be expected to kill fifty percent (50%) of the individuals of the test species organisms in a test of specified length of time.

(L) Losing streams—A stream which distributes thirty percent (30%) or more of its flow through natural processes, such as through permeable geologic materials into a bedrock aquifer within two (2) miles' flow distance downstream of an existing or proposed discharge. Flow measurements to determine percentage of water loss must be corrected to approximate the seven (7)-day Q_{10} stream flow. If a stream bed or drainage way has an intermittent flow or a flow insufficient to measure in accordance with this rule, it may be determined to be a losing stream on the basis of channel development, valley configuration, vegetation development, dye tracing studies, bedrock characteristics, geographical data and other geological factors. A list of known losing streams is available from the Water Pollution Control Program. Other streams may be determined to be losing by the Division of Geology and Land Survey.

(M) Low-flow conditions—

1. Seven (7)-day one (1)-in-ten (10)-year low flow (7-day Q_{10})—The average minimum flow for seven (7) consecutive days that has a probable recurrence interval of once-in-ten (10) years; and

2. Sixty (60)-day, one (1)-in-two (2)-year low flow (60-day, Q_2)—The average minimum flow for sixty (60) consecutive days that has a probable recurrence interval of once-in-two (2) years.

(N) Mixing zone—An area of dilution of effluent in the receiving water beyond which chronic toxicity criteria must be met.

(O) Outstanding national resource waters—Waters which have outstanding national recreational and ecological significance. These waters shall receive special protection against any degradation in quality. Congressionally designated rivers, including those in the Ozark national scenic riverways and the wild and scenic rivers system, are so designated (see Table D).

(P) Outstanding state resource waters—High quality waters with a significant aesthetic, recreational or scientific value which are specifically designated as such by the Clean Water Commission (see Table E).

(Q) Ozark streams—Streams lying within the Ozark faunal region as described in the *Aquatic Community Classification System for Missouri*, Missouri Department of Conservation, 1989.

(R) Reference stream reaches. Stream reaches determined by the department to be the best available representatives of ecoregion waters in a natural condition, with respect to habitat, water quality, biological integrity and diversity, watershed land use and riparian conditions.

(S) Regulated-flow streams—A stream that derives a majority of its flow from an impounded area with a flow-regulating device.

(T) Water hardness—The total concentration of calcium and magnesium ions expressed as calcium carbonate. For purposes of this rule, hardness will be determined by the twenty-fifth percentile value, so that no more than twenty-five percent (25%) of samples fall below the value of a representative number of samples from the water body in question or from a similar water body at the appropriate stream flow conditions.

(U) Water quality criteria—Chemical, physical and biological properties of water that are necessary to protect beneficial water uses.

(V) Zone of initial dilution—A small area of initial mixing below an effluent outfall beyond which acute toxicity criteria must be met.

(W) Zone of passage—A continuous water route necessary to allow passage of organisms with no acutely toxic effects produced on their populations.

(X) Wetlands—Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. This definition is consistent with both the United States Army Corps of Engineers 33 CFR 328.3(b) and the United States Environmental Protection Agency 40 CFR 232.2(r).

(Y) Whole effluent toxicity tests—A toxicity test conducted under specified laboratory conditions on specific indicator organisms. To estimate chronic and acute toxicity of the effluent in its receiving stream, the effluent

may be diluted to simulate the computed percent effluent at the edge of the mixing zone or zone of initial dilution.

(Z) Other definitions as set forth in the Missouri Clean Water Law and 10 CSR 20-2.010 shall apply to terms used in this rule.

(2) Antidegradation. The antidegradation policy shall provide three (3) levels of protection.

(A) Public health, existing in-stream water uses and a level of water quality necessary to protect existing uses shall be maintained and protected.

(B) For all waters of the state, if existing water quality is better than applicable water quality criteria established in these rules, that existing quality shall be fully maintained and protected. Water quality may be lowered only if the state finds, after full satisfaction of the intergovernmental coordination and public participation requirements, that the lowered water quality is necessary to allow important economic and social development in the geographical area in which the waters are located. In allowing the lowering of water quality, the state shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control before allowing any lowering of water quality. This provision allows a proposed new or modified point or nonpoint source of pollution to result in limited lowering of water quality provided that—

1. The source does not violate any of the general criteria set fourth in section (3) of this rule, or any of the criteria for protection of beneficial uses set forth in section (4) of this rule;

2. The source meets all applicable technological effluent limitations and minimum standards of design for point sources or minimum pollution control practices for nonpoint sources; and

3. The lowering of water quality, in the judgment of the department, is necessary for the accommodation of important economic and social development in the geographical vicinity of the discharge. In making a preliminary determination based on socioeconomic development considerations, the department may consider the potential for regional increases in utility rates, taxation levels or recoverable costs associated with the production of goods or services that may result from the imposition of a strict no-degradation policy. Consideration may also be given to the possible indirect effects of a policy on per capita income and the level of employment in the geographical vicinity of the proposed pollution source. Any preliminary decision by the department to allow a limited lowering of water quality will be stated as such in a public notice issued pursuant to 10 CSR 20-6.010. Pursuant to that provision, a public hearing will be held in the geographical vicinity of the proposed pollution source, if the department determines there is significant public interest in and need for a hearing.

(C) There shall be no lowered water quality in outstanding national resource waters or outstanding state resource waters, as designated in Tables D and E.

(3) General Criteria. The following water quality criteria shall be applicable to all waters of the state at all times including mixing zones. No water contaminant, by itself or in combination with other substances, shall prevent the waters of the state from meeting the following conditions:

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses;

(B) Waters shall be free from oil, scum and floating debris in sufficient amounts to be unsightly or prevent full maintenance of beneficial uses;

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses;

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life;

(E) There shall be no significant human health hazard from incidental contact with the water;

(F) There shall be no acute toxicity to livestock or wildlife watering;

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community;

(H) Waters shall be free from used tires, car bodies, appliances, demolition debris, used vehicles or equipment and solid waste as defined in Missouri's Solid Waste Law, section 260.200, RSMo, except as the use of such materials is specifically permitted pursuant to section 260.200—260.247;

(I) Waters in mixing zones and unclassified waters which support aquatic life on an intermittent basis shall be subject to the following requirements:

1. The acute toxicity criteria of Tables A and B and the requirements of subsection (4)(B); and

2. The following whole effluent toxicity conditions must be satisfied:

A. Single dilution method. The percent effluent at the edge of the zone of initial dilution will be computed and toxicity tests performed at this percent effluent. These tests must show statistically insignificant mortality on the most sensitive of at least two (2) representative, diverse species; and

B. Multiple dilution method. An LC_{50} will be derived from a series of test dilutions. The computed percent effluent at the edge of the zone of initial dilution must be less than three-tenths (0.3) of the LC_{50} for the most sensitive of at least two (2) representative, diverse species.

(4) Specific Criteria. The specific criteria shall apply to classified waters. Protection of drinking water supply is limited to surface waters designated for raw drinking water supply and aquifers. Protection of whole-body-contact recreation is limited to classified waters designated for that use. Only waters designated for livestock and wildlife watering are considered to be long-term supplies and are subject to the chronic toxicity requirements of the specific criteria.

(A) The maximum chronic toxicity criteria in Tables A and B shall apply to waters designated for the indicated uses given in Tables G and H. All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute criteria. Water contaminants shall not cause or contribute to concentrations in excess of these values. However, exceptions may be granted in the following cases:

1. Permanent flow streams when the stream flow is less than seven (7)-day Q_{10};

2. Regulated flow streams if the flow is less than the minimum release flow agreed upon by the regulating agencies;

3. When natural upstream concentrations of dissolved oxygen are below the criteria, wasteload allocations and permits for point source discharges will be developed so that existing natural dissolved oxygen concentrations, as determined on a regional or watershed basis, are maintained;

4. For the natural and unavoidable chemical and physical changes that occur in the hypolimnion of lakes. Streams below impoundments shall meet applicable specific criteria;

5. For mixing zones.

A. The mixing zone shall be exempted from the chronic criteria requirements of this section for those components of waste that are rendered nontoxic by dilution, dissipation or rapid chemical transformation. Acute numeric criteria of Tables A and B and whole effluent acute toxicity requirements of subsection (3)(I) must be met at all times within the mixing zone, except within the zone of initial dilution.

The following criteria do not apply to thermal mixing zones. Criteria for thermal mixing zones are listed in paragraph (4)(D)6.

B. The maximum size of mixing zones and zone of initial dilution will be determined as follows:

(I) Class C streams and streams with seven (7)-day Q_{10} low flows of 0.1 cfs or less.

(a) Mixing zone—length of one-quarter (1/4) mile. If multiple discharges affect a reach or if zone of passage requirements mandate less extensive mixing zones, shorter mixing zones may be required.

(b) Zone of initial dilution—not allowed;

(II) Streams with seven (7)-day Q_{10} low flow of one-tenth to twenty (0.1—20) cfs—

a. Mixing zone—one-quarter (1/4) of the stream width, cross-sectional area or volume of flow; length one-quarter (1/4) mile. If the discharger can document that rapid and complete mixing of the effluent occurs in the receiving stream, the mixing zone may be up to one-half (1/2) of the stream width, cross-sectional area or volume of flow; and

b. Zone of initial dilution—one-tenth (0.1) of the mixing zone width, cross-sectional area or volume of flow;

(III) Streams with seven (7)-day Q_{10} low flow of greater than twenty (20) cfs—

a. Mixing zone—one-quarter (1/4) of stream width, cross-sectional area or volume of flow; length of one-quarter (1/4) mile; and

b. Zone of initial dilution—one-tenth (0.1) of the mixing zone width, cross-sectional area or volume of flow and no more than ten (10) times the effluent design flow volume unless the use of diffusers or specific mixing zone studies can justify more dilution; and

(IV) Lakes.

(a) Mixing zone—not to exceed one-quarter (1/4) of the lake width at the discharge point or one hundred feet (100') from the discharge point, whichever is less.

(b) Zone of initial dilution—not allowed.

C. A mixing zone shall not overlap another mixing zone in a manner that the maintenance of aquatic life in the body of water in the overlapping area would be further adversely affected.

D. Other factors that may prohibit or further limit the size and location of mixing zones are the size of the river, the volume of discharge, the stream bank configuration, the mixing velocities, other hydrologic or physiographic characteristics and the designated uses of the water, including type of aquatic life supported, potential effects on mouths of tributary streams and proximity to water supply intakes.

E. Zones of passage must be provided wherever mixing zones are allowed.

F. Mixing zone and zone of initial dilution size limits will normally be based on streams at the seven (7)-day Q_{10} low flow. However, this percent of stream size limits also applies at higher stream flows and discharge limitations may be based on higher stream flows if discharge volume or quality may be adjusted to correlate with stream flow; and

6. For wetlands. Water quality needs will vary depending on the individual characteristics of wetlands. Application of numeric criteria will depend on the specific aquatic life, wildlife and vegetational requirements.

(B) Toxic Substances.

1. Water contaminants shall not cause the criteria in Tables A and B to be exceeded. Concentrations of these substances in bottom sediments or waters shall not harm benthic organisms and shall not accumulate through the food chain in harmful concentrations, nor shall state and federal maximum fish tissue levels for fish consumption be exceeded. More stringent criteria may be imposed if there is evidence of additive or synergistic effects. Site-specific criterial modifications may be allowed. With the department's approval, entities may conduct studies to determine if site-specific factors would justify modifications in the criteria that apply to specific receiving waters. In approving a study and reviewing its results, the department will take into account EPA and other appropriate guidelines as they exist at the time the study is submitted for approval.

2. For compliance with this rule, metals shall be analyzed by the following methods:

A. Aquatic life protection and human-health protection—fish consumption.

(I) Mercury—total recoverable metals.

(II) All other metals—dissolved metals;

B. Drinking water supply—dissolved metals; and

C. All other beneficial uses—total recoverable metals.

3. Other potentially toxic substances for which sufficient toxicity data are not available may not be released to waters of the state until safe levels are demonstrated through adequate bioassay studies.

4. Drinking water criteria, for substances which are rendered nontoxic by transformation processes in the surface water body, shall apply at water supply withdrawal points.

5. Site-specific alternative criteria for human health—fish consumption may be allowed. Designation of this site-specific criteria must follow the established variance request process.

(C) Fecal Coliform Bacteria. Protections of whole-body-contact recreation is limited to classified waters designated for that use. For periods when the stream or lake is not affected by stormwater runoff, the fecal coliform count shall not exceed two hundred colonies per one hundred milliliters (200/100 ml) during the recreational season in waters designated for whole-body-contact recreation or at any time in losing streams. The recreational season is from April 1 to October 31.

(D) Temperature.

1. For general and limited warm-water fisheries beyond the mixing zone, water contaminant sources and physical alteration of the water course shall not raise or lower the temperature of a stream more than five degrees Fahrenheit (5°F). Water contaminant sources shall not cause or contribute to stream temperature in excess of ninety degrees Fahrenheit (90°F). However, site-specific ambient temperature data and requirements of sensitive resident aquatic species will be considered, when data are available, to establish alternative maxima or deviations from ambient temperatures.

2. For cool-water fisheries beyond the mixing zone, water contaminant sources and physical alteration of the water course shall not raise or lower the temperature of a stream more than five degrees Fahrenheit (5°F). Water contaminant sources shall not cause or contribute to stream temperature in excess of eighty-four degrees Fahrenheit (84°F).

3. For cold-water fisheries beyond the mixing zone, water contaminant sources and physical alteration of the water course shall not raise or lower the temperature of the water body more than two degrees Fahrenheit (2°F). Water contaminant sources shall not cause or contribute to temperatures above sixty-eight degrees Fahrenheit (68°F).

4. Water contaminant sources shall not cause any measurable rise in the temperature of lakes. An increase is allowable for Lake Springfield, Thomas Hill Reservoir and Montrose Lake; however, discharges from these lakes must comply with temperature limits for streams.

5. For the Mississippi River Zones 1A and 2, the water temperature outside the mixing zone shall not exceed the maximum limits indicated in the following list during more than one percent (1%) of the time in any calendar year. In Zone 1B, limits may not be exceeded more than five percent (5%) of the time in a calendar year. At no time shall the river water temperature outside of the thermal mixing zone exceed the listed limits by more than three degrees Fahrenheit (3°F).

	A,B (°F)	C (°F)
January	45	50
February	45	50
March	57	60
April	68	70
May	78	80
June	86	87
July	88	89
August	88	89
September	86	87
October	75	78
November	65	70
December	52	57

A = Zone 1A—Des Moines River to Lock and Dam No. 25

B = Zone 1B—Lock and Dam No. 25 to Lock and Dam No. 26.

C = Zone 2—Lock and Dam No. 26 to the Missouri-Arkansas state line

6. Thermal mixing zones shall be limited to twenty-five percent (25%) of the cross-sectional area or volume of a river, unless biological surveys performed in response to section 316(a) of the federal Clean Water Act (or equivalent) indicate no significant adverse impact on aquatic life. Thermal plume lengths and widths within rivers, and all plume dimensions within lakes, shall be determined on a case-by-case basis and shall be based on physical and biological surveys when appropriate.

(E) pH. Water contaminants shall not cause pH to be outside of the range of 6.5—9.0.

(F) Taste- and Odor-Producing Substances. Taste- and odor-producing substances shall be limited to concentrations in the streams or lakes that will not interfere with beneficial uses of the water. For those streams and lakes designated for drinking water supply use, the taste- and odor-producing substances shall be limited to concentrations that will not interfere with the production of potable water by reasonable water treatment processes.

(G) Turbidity and Color. Water contaminants shall not cause or contribute to turbidity or color that will cause substantial visible contrast with the natural appearance of the stream or lake or interfere with beneficial uses.

(H) Solids. Water contaminants shall not cause or contribute to solids in excess of a level that will interfere with beneficial uses. The stream or lake bottom shall be free of materials which will adversely alter the composition of the benthos, interfere with the spawning of fish or development of their eggs or adversely change the physical or chemical nature of the bottom.

(I) Radioactive Materials. All streams and lakes shall conform with state and federal limits for radionuclides established for drinking water supply.

(J) Dissolved Oxygen. Water contaminants shall not cause the dissolved oxygen to be lower than the levels described in Table A or as indicated in paragraph (4)(A)3.

(K) Total Dissolved Gases. Operation of impoundments shall not cause the total dissolved gas concentrations to exceed one hundred ten percent (110%) of the saturation value for gases at the existing atmospheric and hydrostatic pressures.

(L) Sulfate and Chloride Limit for Protection of Aquatic Life.

1. Streams with seven (7)-day Q_{10} low flow of less than one (1) cubic foot per second. The concentration of chloride plus sulfate shall not exceed one thousand milligrams per liter (1000 mg/l) at the seven (7)-day Q_{10} low flow. Table A includes additional chloride criteria.

2. Class P1, L1, L2 and L3 waters and streams with seven (7)-day Q_{10} low flow of more than one (1) cubic foot per second. The total chloride plus sulfate concentration shall not exceed the estimated natural background concentration by more than twenty percent (20%) at the sixty (60)-day Q_2 low flow.

3. If higher concentrations can be demonstrated through bioassays or studies not to be detrimental to indigenous aquatic life, then an appropriate higher concentration shall be allowed.

(M) Carcinogenic Substances. Carcinogenic substances shall not exceed concentrations in water which correspond to the 10^{-6} cancer risk rate. This risk rate equates to one (1) additional cancer case in a population of one (1) million with lifetime exposure. Derivation of this concentration assumes average water and fish consumption amounts. Assumptions are two (2) liters of water and 6.5 grams of fish consumed per day. Federally established final maximum contaminant levels for drinking water supply shall supersede drinking water supply criteria developed in this manner.

(N) All methods of sample collection, preservation and analysis used in applying criteria in these standards shall be in accord with those prescribed in the latest edition of *Standard Methods for the Examination of Water and Wastewater* or other procedures approved by the Environmental Protection Agency and the Missouri Department of Natural Resources.

(O) Criteria to protect designated uses are based on current technical literature, especially the Environmental Protection Agency's publication, *Quality Criteria for Water*, 1986. Criteria may be modified or expanded as additional information is developed or as needed to define narrative criteria for particular situations or locations.

(P) WET Chronic Tests. Chronic WET tests performed at the percent effluent at the edge of the mixing zone shall not be toxic to the most sensitive of at least two (2) representative, diverse species. Pollutant attenuation processes such as volatilization and biodegradation which may occur within the allowable mixing zone will be considered in interpreting results.

(Q) Biocriteria. The biological integrity of waters, as measured by lists or numeric diversity indices of benthic invertebrates, fish, algae or other appropriate biological indicators, shall not be significantly different from reference waters. Waters shall be compared with reference waters of similar size within an ecoregion. Reference water locations are listed in Table I.

(5) Groundwater.

(A) Water contaminants shall not cause or contribute to exceedence of Table A, Column VII limits in aquifers and caves. Substances not listed in Table A shall be limited so that drinking water, livestock watering and irrigation uses are protected.

(B) When criteria in Column I or II of Table A are more stringent than Column VII criteria, appropriate Column I or II criteria shall apply to waters in caves and to aquifers which contribute an important part of base flow of surface waters designated for aquatic life protection. Other substances not listed in Table A shall be limited in these aquifers and caves so that the aquatic life use is protected.

(C) Column VII and other criteria shall apply in any part of the aquifer, including the point at which the pollutant enters the aquifer. A specific monitoring depth requirement for releases to aquifers is included in 10 CSR 20-7.015(7)(A).

(D) For aquifers in which contaminant concentrations exceed Column VII criteria or other protection criteria, and existing and potential uses are not impaired, alternative site-specific criteria may be allowed. To allow alternative criteria, the management authority must demonstrate that alternative criteria will not impair existing and potential uses. The demonstration must consider the factors and be subject to the review requirements of 10 CSR 20-7.015(7)(F).

(6) Metropolitan No-Discharge Streams. No water contaminant except uncontaminated cooling water, permitted stormwater discharges in compliance with permit conditions and excess wet-weather bypass discharges not interfering with beneficial uses, shall be discharged to streams listed in Table F. Existing interim discharges may be allowed

until interceptors are available within two thousand feet (2000') or a distance deemed feasible by the department, or unless construction of outfalls to alternative receiving waters not listed in Table F is deemed feasible by the department. Existing discharges include wastewater volumes up to the design capacity of existing permitted treatment facilities, including phased increases in design capacity approved by the department prior to the effective date of this rule. Additional facilities may be constructed to discharge to these waters only if they are intended to be interim facilities in accordance with a regional wastewater treatment plan approved by the department.

(7) Outstanding National Resource Waters. Under section (2), antidegradation section of this rule, new releases to outstanding national resource waters from any source other than publicly-owned waste treatment facilities and mine dewatering water are prohibited and releases from allowed facilities are subject to special effluent limitations as required in 10 CSR 20-7.015(6)(B)3. Table D contains a list of outstanding national resource waters.

(8) Outstanding State Resource Waters.

(A) The commission wishes to recognize certain high-quality waters that may require exceptionally stringent water-quality management requirements to assure conformance with the antidegradation policy. The degree of management requirements will be decided on an individual basis. To qualify for inclusion, all of the following criteria must be met. The waters listed in Table E must—

1. Have a high level of aesthetic or scientific value;
2. Have an undeveloped watershed; and
3. Be located on or pass through state or federally owned lands.

(9) Lake Taneycomo. The commission wishes to recognize the uniqueness of Lake Taneycomo with respect to its high water clarity, its importance as a trout fishery and as the central natural resource in the rapidly developing Branson area and threats to the lake's water quality imposed by development. An especially stringent antidegradation policy will be observed in the development of effluent rules, discharge permits and nonpoint-source management plans and permits to assure that the high visual quality and aquatic resources are maintained. The use of the best treatment technology for point- and nonpoint-source discharges in the lake's watershed between Table Rock Lake and Power Site Dam will be the guiding principle in establishing limitations.

(10) Compliance with new or revised National Pollutant Discharge Elimination System (NPDES) or Missouri operating permit limitations based on criteria in this rule shall be achieved with all deliberate speed and no later than three (3) years from the date of issuance of the permit.

(11) Severance. If a section, subsection, paragraph, sentence, clause, phrase or any part of this rule be declared unconstitutional or invalid for any reason, the remainder of this rule shall not be affected and shall remain in full force and effect.

(12) Effective Date. This rule becomes effective immediately upon adoption and compliance with the requirements of subsection 644.036.3. of the Missouri Clean Water Law and Chapter 536, RSMo.

Auth: sections 644.021, RSMo (1986) and 644.026, RSMo (Supp. 1987). Original rule filed May 13, 1977, effective Dec. 11, 1977. Amended: Filed Oct. 15, 1980, effective April 11, 1981. Amended: Filed July 12, 1984, effective Dec. 13, 1984. Rescinded and readopted: Filed Aug. 4, 1987, effective Dec. 12, 1987. Amended: Filed Nov. 14, 1988, effective April 15, 1989. Rescinded and readopted: Filed Sept. 5, 1990, effective March 14, 1991. Amended: Filed Sept. 2, 1993, effective May 9, 1994.

**Original authority: 644.021, RSMo (1972), amended 1973 and 644.026, RSMo (1972), amended 1973, 1987.*

Table A—Criteria for Designated Uses

I = Protection of Aquatic Life
II = Human Health Protection—Fish Consumption
III = Drinking Water Supply
IV = Irrigation
V = Livestock, Wildlife Watering
VI = Whole-Body-Contact Recreation
VII = Groundwater

Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Chlorine (total residual)							
cold-water	2						
warm-water chronic—	10						
acute—.	19						
Cyanide (amenable to chlorination)							
chronic toxicity	5						
acute toxicity	22						
Hydrogen sulfide	2						

Pollutant (mg/l)	I	II	III	IV	V	VI	VII
Chloride chronic—	230(+)		250				
acute—	860(+)						
Sulfate	(−)		250				
Fluoride			4		4		4
Nitrate-N			10				10
Dissolved oxygen (minimum)							
warm-water and cool-water fisheries	5						
cold-water fisheries	6						
Oil and grease	10						

−See subsection (4)(L).

Pollutant (/100 ml)	I	II	III	IV	V	VI	VII
Fecal Coliform Bacteria						200	

Pollutant (°F)	I	II	III	IV	V	VI	VII
Temperature (maximum)							
warm-water	90						
cool-water	84						
cold-water	68						
Temperature (maximum change)							
warm-water	5						
cool-water	5						
cold-water	2						

Pollutant (percent saturation)	I	II	III	IV	V	VI	VII
Total Dissolved Gases	110%						

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Pollutant (µg/l)		I			II	III	IV	V	VI	VII
Metals										
Aluminum (acute)		750								
Antimony					4300	6				6
Arsenic		20				50	100			50
Barium						2000				2000
Beryllium		5				4	100			4
Boron							2000			2000
Cadmium			Hardness			5				5
		<125	125–200	>200						
	chronic:									
	CWF	1.2	1.5	2						
	Lakes	10	10	10						
	GWWF	10	13	17						
	LWWF	13	18	22						
	acute:									
	CWF	3.9	6.2	8.6						
	Lakes & GWWF	33	52	72						
	LWWF	46	72	100						
Chromium						100	100			100
	chronic:									
	Lakes	11 µg/l								
	CWF, GWWF	42								
	LWWF	190								
	acute:									
	Lakes	16 µg/l								
	CWF & GWWF	62								
	LWWF	280								
Cobalt								1000		1000
Copper			Hardness			1300		500		1300
		<125	125–200	>200						
	chronic:									
	Lakes, CWF, GWWF	20 µg/l	29	37						
	LWWF	30	43	55						
	acute:									
	Lakes, CWF, GWWF	30	45	58						
	LWWF	46	67	88						
Iron		1000				300				300
Lead			Hardness			15				15
		<125	125–200	>200						
	chronic:									
	all waters	12	20	29						
	acute:									
	all waters	80	130	190						

CWF = Cold-water fishery
GWWF = General warm-water fishery
LWWF = Limited warm-water fishery

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Pollutant (µg/l)		I			II	III	IV	V	VI	VII
Manganese						50				50
Mercury						2				2
	chronic:									
	all waters	0.5								
	acute:									
	all waters	2.4								
Nickel			Hardness			100				100
		≤125	125–200	>200						
	chronic:									
	Lakes	160	220	280						
	CWF, GWWF	360	500	650						
	LWWF	425	600	770						
	acute:									
	Lakes	1400	2000	2500						
	CWF, GWWF	3200	4600	5800						
	LWWF	3800	5400	6900						
Selenium		5				50				50
Silver			Hardness			50				50
		≤125	125–200	>200						
	acute:									
	all waters	4.1	8.2	13						
Thallium					6.3	2				2
Zinc			Hardness			5000				5000
		≤125	125–200	>200						
	chronic:									
	CWF	175	240	310						
	Lakes	105	150	190						
	GWWF	245	345	440						
	LWWF	1065	1505	1920						
	acute:									
	CWF	190	270	345						
	Lakes	115	165	210						
	GWWF	270	380	490						
	LWWF	1180	1660	2120						

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Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Organics							
Acenaphthene		2700	20				20
Acrolein		780	320				320
Bis-2-chloroisopropyl ether		4360	35				35
2 chlorophenol		400	.1				.1
2,4-dichlorophenol	7	790	93				93
2,4-dinitrophenol		14000	70				70
2,4-dimethylphenol		2300	540				540
2,4,5-trichlorophenol		9800	1				1
2,4,6-trichlorophenol		7	2				2
2-methyl-4,6-dinitrophenol		765	13				13
Ethylbenzene	320		700				700
Hexachlorocyclopentadiene	.5		50				50
Isophorone		2600	36				36
Nitrobenzene		1900	17				17
Phenol	100		1				300
Dichloropropene		1700	10				10
Fluoranthene		54	40				40
Para(1,4)-dichlorobenzene		2600	75				75
Other Dichlorobenzenes		2600	400				400
1,2,4-trichlorobenzene		940	70				70
1,2,4,5-tetrachlorobenzene		2.9	2.3				2.3
pentachlorobenzene		85	74				74
1,1,1-trichloroethane			200				200
1,1,2-trichloroethane		42	5				5
2,4-dinitrotoluene		9	.11				.11
1,2-diphenylhydrazine		.54	.04				.04
di (2-ethylhexyl) adipate			400				400
n-nitrosodiphenylamine		16	5				5
n-nitrosopyrrolidene		93					
2-chloronaphthalene	4300						
n-nitrosodi-n-propylamine		1.4					

Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Pesticides							
Demeton	.1						
Endosulfan							
Chronic—	.056						
Acute—	0.11						
Guthion	.01						
Malathion	.1						
Parathion	.04						
2,4-D			70				70
2,4,5-TP			50				50
Chlorpyrifos	.04						
Alachlor			2				2
Atrazine			3				3
Carbofuran			40				40
Dalapon			200				200
Dibromochloropropane			.2				.2
Dinoseb			7				7
Diquat			20				20
Endothall			100				100
Ethylene dibromide			.05				.05
Oxamyl (vydate)			200				200
Picloram			500				500
Simazine			4				4

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Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Persistent, Bioaccumulative, Man-Made Toxics(–)							
PCB's		.000045					.000045
DDT and metabolites		.000024					.000024
Endrin		.0023	2				2
Endrin aldehyde		.0023	.75				.75
Aldrin		.000079	.000074				.000074
Dieldrin		.000076	.000071				.000071
Heptachlor	.0038	.0002	0.4				0.4
Heptachlor epoxide		.00011	0.2				0.2
Methoxychlor	.03		40				40
Mirex	.001						
Toxaphene		.000073	3				3
Lindane (gamma-BHC)		.062	.2				.2
Alpha,beta,delta-BHC		.0074	.0022				.0022
Chlordane		.00048	2				2
Benzidine		.00053	.00012				.00012
2,3,7,8-TCDD(dioxin)(ng·l)*		.000014	.03				.03
Pentachlorophenol**	3.2—pH 6.5 5.3—pH 7.0 8.7—pH 7.5 14—pH 8.0 23—pH 8.5	8	1				1

–Many of these values are below current detection limits; analyses will be determined by the 17th edition of *Standard Methods* or the most current methods approved by the Environmental Protection Agency.

*Units for dioxin are nanograms liter (ng/l); 1 ug/l = 1000 ng/l.

**Toxic impurities may be present in technical-grade pentachlorophenol; monitoring and discharge control will assure that impurities are below toxic concentrations.

I = Protection of Aquatic Life
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Pollutant (µg/l)	I	II	III	IV	V	VI	VII
Persistent, Manmade Carcinogens(−) µg/l							
Acrylonitrile		.65	.058				.058
Hexachlorobenzene		.00074	1				1
Bis (2-chloroethyl) ether		1.4	.03				.03
Bis (chloromethyl) ether		.07	.00016				.00016
Hexachloroethane		8.7	1.9				1.9
3,3'-dichlorobenzidine		0.08	.04				.04
Hexachlorobutadiene		50	.45				.45
n-nitrosodimethylamine		8	.0007				.0007

(−) Some of these values are below current detection limits; analyses will be determined by the 17th edition of *Standard Methods* or the most current methods approved by the Environmental Protection Agency.

Pollutant (µg/l)	I	II	III	IV	V	VI	VII
Volatile Organics							
Chlorobenzene		21,000	100				100
Carbon Tetrachloride		5	5				5
Trihalomethanes			100				100
Methyl Bromide		4000	48				48
Methyl Chloride		470	5				5
Methylene Chloride		1600	5				5
Bromoform		365					
Chlorodibromomethane		35					
Dichlorobromomethane		46					
Dichlorodifluoromethane		570,000					
Trichlorofluoromethane		860,000					
1,2-dichloroethane		99	5				5
1,1,2,2-tetrachloroethane		11	.17				.17
1,1-dichloroethylene		3.2	7				7
1,2-trans-dichloroethylene		140,000	100				100
Trichloroethylene		80	5				5
Tetrachloroethylene		9	5				5
Benzene		71	5				5
Toluene		200,000	1000				1000
Xylenes (total)			10,000				10,000
Vinyl chloride		525	2				2
Styrene			100				100
1,2-dichloropropane		39	100				100

Pollutant (fibers/l)	I	II	III	IV	V	VI	VII
Asbestos			7,000,000				

Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Polynuclear Aromatic Hydrocarbons							
Anthracene		110,000	9600				9600
Fluoranthene		370	300				300
Fluorene		14,000	1300				1300
Pyrene		11,000	960				960
Benzo(a)pyrene		.049	0.2				0.2
other polynuclear aromatic hydrocarbons*		.049	.0044				.0044

*This concentration is allowed for each of the following PAHs: acenaphthylene, anthracene, benzo(a)anthracene, 3,4-benzofluoranthene, chrysene, dibenzo(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, benzo(g,h,i)pyrelene and benezo(k)fluoranthene. Higher values may be allowed if natural background concentrations exceed these values.

Pollutant (ug/l)	I	II	III	IV	V	VI	VII
Phthalate Esters							
Bis(2-ethylhexyl) phthalate		5.9	6				6
Butylbenzyl phthalate		5200	3000				3000
Diethyl phthalate		120,000	23,000				23,000
Dimethyl phthalate		2,900,000	313,000				313,000
Di-n-butyl phthalate		12,000	2700				2700

APPENDIX 4
NONSTRUCTURAL BMPs

APPENDIX 4
NON-STRUCTURAL BMPS

In developing a plan to protect the Fulbright Spring recharge area, it should be remembered that structural BMPs are only one part of an overall BMP program. The most effective way to maintain clean surface water is to eliminate the sources of pollution, not to remove pollution once it has gotten into the system. Thus, the municipality (and many sites) should be implementing a "baseline" BMP program which includes nonstructural educational, regulatory and programmatic BMPs.

Close attention to the nature of site design and layout can go a long way toward reducing pollution. For example, landscaping and terracing provide natural buffers, rainfall holding and infiltration areas. Use of low maintenance, locally derived vegetation reduces the need for pesticides and fertilizer. Directing roof and driveway runoff across grassy areas provides a natural filtration and infiltration. Clustering designs, zoning density limitations, critical area identification and protection, and joint regional design planning can all work toward an inherent lowering of pollution loading levels.

The following pages give information on non-structural or source BMPs. All of these BMPs have application within the Fulbright Spring watershed although all may not be needed, and some may find wider application than others. All of these BMPs have the potential to have significant impacts on surface and groundwater quality depending on the extent to which they are implemented.

The following discussion of each BMP is divided into six categories as follows:

1. BMP (gives the general BMP name or category)
2. Description (describes the general characteristics of the BMP)
3. Classification (these are source/non-structural BMPs)
4. General Applicability and Experience with Technique Elsewhere
5. Additional Information
6. Cost Considerations

A-1. BMP: Public Education/Participation

A-2. Description

Public education/participation, like an ordinance or a piece of equipment, is not so much a best management practice as it is a method by which to implement BMPs. Public education/participation are vital components of many of the individual source control BMPs that follow in this report.

A public education and participation plan provides the municipality with a strategy for educating its employees, the public, and businesses about the importance of protecting storm water from improper use, storage, and disposal of pollutants. Municipal employees must be trained, espe-

cially those that work in departments not directly related to storm water but whose actions affect storm water. Residents must become aware that a variety of hazardous products are used in the home and that their improper use and disposal can pollute storm water and groundwater supplies. Businesses, particularly smaller ones that may not be regulated by Federal, State, or local regulations, must be informed of ways to reduce their potential to pollute storm water.

The public education and participation plan should be based on four objectives:

- promote a clear identification and understanding of the problem and the solutions,
- identify responsible parties and efforts to date,
- promote community ownership of the problems and the solutions, and
- integrate public feedback into program implementation.

A-3. Classification: Source/Non-Structural BMP

A-4. General Applicability and Experience with Technique Elsewhere

There are a number of communities with effective public education/participation programs. The most proactive include the City and County of San Francisco, the Municipality of Metropolitan Seattle, North Central Texas and the Unified Sewerage Agency of Washington County, Oregon. In addition, some utilities have used inserts in their bill mailings to educate their customers. Less formal programs have been used in Greenville, South Carolina and Charlotte, North Carolina.

A-5. Additional Information

Each public education/participation program is specifically designed and developed for the needs of the particular municipality. Typical target audiences include:

- Political - elected officials, chambers of commerce, and heads of departments, agencies, and commissions;
- Technical - municipal department and agency staffs, State agencies;
- Business - commercial and industrial, including trade associations;
- Community groups - fraternal, ethnic, hobby, horticulture, senior citizen, and service;
- Environmental;
- General public/residential;
- Schools/youth groups;
- Media - print and electronic, and
- Pollutant-defined - groups of individuals defined by the specific pollutant(s) they discharge (e.g., used motor oil, pesticides)

For these target audiences the activities within the public education/participation plan can include surveys, presentations, school activities, development of working committees, development of literature and media campaigns, workshops, etc. All of these activities can be an important part of controlling local storm water management problems.

A-6. Cost Considerations

The major costs associated with Public Education/Participation is costs for development of the plan elements and startup costs. These will be highly dependent on the scope of the elements included in the plan.

B-1. BMP: Land Use Planning/Management

B-2. Description

This BMP presents an important opportunity to reduce the pollutants in stormwater runoff by using a comprehensive planning process to control or prevent certain land use activities in areas where water quality is sensitive to development. It is applicable to all types of land use and represents one of the most effective pollution prevention practices.

Subdivision regulations, zoning ordinances, preliminary plan reviews and detailed plan reviews are tools that may be used to mitigate storm water contamination in newly developing areas. These are planning tools that municipal agencies can use to require conditions of approval or establish improvement/construction standards to meet the water quality objectives within specific watersheds.

An impervious cover limitation is one of the more effective land use management tools, since nationwide research has consistently documented increases in pollution loads with increases in impervious cover.

B-3. Classification: Source/Non-Structural BMP

B-4. General Applicability and Experience with Technique Elsewhere

The City of Austin, Texas, has chosen to manage the impact of new development in two fundamental ways: through control requirements and impervious area minimization requirements. Austin, through its Comprehensive Watershed Ordinance, requires that impervious cover on residential development in certain areas of the city be limited to 15 to 25 percent. Sedimentation and filtration ponds which will capture and treat the first one-half inch of runoff from a site are required for developments of higher intensity, such a commercial developments.

In compliance with state water supply watershed regulations, municipalities in North Carolina have adopted impervious area limitations. These limitations are quite complex since there are five different classifications of watersheds, depending on the amount of existing development. However, following are the general requirements:

Critical Areas (near water supply points) - 12 percent impervious area without structural BMPs
12-30 percent impervious area with structural BMPs

Entire Watershed - 24 percent impervious area without structural BMPs
24-50 percent impervious area with structural BMPs

In addition, BMPs for agriculture, forestry and transportation are required. Other features include provisions for cluster developments, no landfills, encouragement of sewer lines, control of one-inch storm for structural BMPs.

Other municipalities and states are relying on the NPDES permitting system under the EPA water quality regulations to determine allowable discharges. The State of Georgia is using its erosion control law to regulate the amount of sediment that discharges into streams by setting NTU (turbidity units) limits.

B-5. Additional Information

In addition to controlling impervious area cover, directly connected impervious areas are kept to a minimum. This is especially important for parking lots and highways and not as important for roof drainage, especially from residential buildings.

Land use planning/management frequently addresses sensitive public issues and will generally develop policies that will not be universally accepted within the municipality. As such, implementation of the necessary restrictions on certain land uses required to mitigate stormwater pollution may not be politically feasible.

B-6. Cost Considerations

The majority of costs are associated with establishing a comprehensive land use plan which addresses the quality of storm water runoff after projects are completed. Other costs are associated with lower intensive land uses being allowed to develop, cost of structural BMPs where required, and development of ordinances and regulations to implement the land use plan and provisions. In practice, implementing land use planning can be one of the most cost-effective means of storm water quality management because it prevents or limits activities on watersheds that generate significant pollution and results in minimal long-term maintenance costs.

C-1. BMP: Material Use Controls

C-2. Description

There are three major BMPs included in this category:

1. Housekeeping Practices
2. Safer Alternative Products
3. Pesticide/Fertilizer Use

In housekeeping practices, the goal is to promote efficient and safe housekeeping practices (storage, use, cleanup, and disposal) when handling potentially harmful materials such as fertilizers, pesticides, cleaning solutions, paint products, automotive products, and swimming pool chemicals. In addition, the municipality can promote the use of less harmful products. Alternatives exist for most product classes including fertilizers, pesticides, cleaning solutions, and automotive and paint products.

Pesticides and fertilizers have become an important component of land use and maintenance for municipalities, commercial land uses and residential land owners. Any usage of pesticides and fertilizers increases the potential for stormwater pollution. BMPs for pesticides and fertilizers include education of their use, control of runoff from affected areas, control of times when they are used, provisions of proper disposal areas, etc.

C-3. Classification: Source/Non-Structural BMP

C-4. General Applicability and Experience with Technique Elsewhere

There are a number of communities with programs for material use controls including Santa Clara County and the City of Palo Alto, California, the City and County of San Francisco, and the Municipality of Metropolitan Seattle. Such programs are being developed in Charlotte, North Carolina.

C-5. Additional Information

For the general public, municipalities should establish a public education program that provides information on such items as stormwater pollution and the beneficial effects of proper disposal on water quality; reading product labels; safer alternative products; safe storage, handling, and disposal of hazardous products; list of local agencies; and emergency phone numbers. This information can be provided through brochures or booklets that can be made available at a variety of places including municipal offices and places where such products are sold, household hazardous waste collection events or facilities, and public information fairs. Educational programs should also be developed for municipal employees and commercial and industrial establishments.

C-6. Cost Considerations

The primary costs are for staff time to develop the programs and provide the education and training.

D-1. BMP: Material Exposure Controls

D-2. Description

There are two major BMPs included in this category:

1. Material Storage Control
2. Vehicle Use Reduction

Material storage control is used to prevent or reduce the discharge of pollutants to stormwater from material delivery and storage by minimizing the storage of hazardous materials onsite, storing materials in a designated area, installing secondary containment, conducting regular inspections, and training employees and subcontractors.

Vehicle use reduction is used to reduce the discharge of pollutants to stormwater from vehicle use by high-lighting the stormwater impacts, promoting the benefits to stormwater of alternative transportation, and integrating initiatives with existing or emerging regulations and programs.

D-3. Classification: Source/Non-Structural BMP

D-4. General Applicability and Experience with Technique Elsewhere

These two BMPs are applicable to most municipalities although documented use and experience is limited.

D-5. Additional Information

The major problem with storage controls is providing storage areas and containers and developing programs for their inspection and maintenance. Education programs will be needed to implement storage controls and for vehicle use reduction. Areas for storage of materials and reduction of vehicle use should be considered in all land use plans.

D-6. Cost Considerations

Cost considerations will vary depending on the size of the facility needed for storage and the necessary controls. The major cost for vehicle use reduction is for staff time for education programs and to help coordinate programs such as ride sharing.

E-1. BMP: Material Disposal and Recycling

E-2. Description

There are three major BMPs included in this category:

1. Storm Drain System Signs
2. Household Hazardous Waste Collection
3. Used Oil Collection

Stenciling of the stormdrain system (inlets, catch basins, channels, and creeks) with prohibitive language/graphic icons discourages the illegal dumping of unwanted materials.

Household hazardous wastes are defined as waste materials which are typically found in homes or similar sources, which exhibit characteristics such as: corrosivity, ignitability, reactivity, and/or toxicity, or are listed as hazardous materials by the EPA.

Used oil recycling is a responsible alternative to improper disposal practices such as dumping oil in the sanitary sewer or storm drain system, applying oil to roads for dust control, placing used oil and filters in the trash for disposal to landfill, or simply pouring used oil on the ground.

E-3. Classification: Source/Non-Structural BMP

E-4. General Applicability and Experience with Technique Elsewhere

The City of Palo Alto, California has a combined volunteer/contractor program which greatly facilitates storm drain stenciling. The City retained the Conservation Corps to paint approximately 75 percent (2,000) of it's storm drains, leaving the 25 percent (700) of its drains in more residential areas to be done by volunteers. In the northeast, all facilities that drain to the Potomac River are stenciled. Seattle/King County, WA has a mobile collection program for hazardous waste collection that was initiated in 1989. San Francisco, California is one of the oldest (1988) and most convenient permanent collection centers in the country. In 1991 over 60 percent of the waste collected was recycled, about 25 percent burned as fuel, 10 percent incinerated, 2 percent neutralized, and less than 2 percent sent to the landfill. For oil collection, a nationally recognized used oil program is Project R.O.S.E. (Recycled Oil Saves Energy), operated by the University of Alabama and funded by the Science, Technology and Energy Division of the Alabama Department of Economic and Community Affairs.

E-5. Additional Information

Storm drain system signs act as highly visible source controls that are typically stenciled directly adjacent to storm drain inlets. The signs contain brief statements that discourage the dumping of improper materials into the storm drain system. Graphical icons, either illustrating anti-dumping symbols or images of receiving water fauna, are effective supplements to the anti-dumping message. The intent of storm drain system stenciling programs is to enhance public

awareness of the pollutant effect on local receiving waters from stormwater runoff and also to discourage individual's habitual waste disposal actions (i.e., automotive fluids and landscaping wastes). An important aspect of a stenciling program is the distribution of informational flyers that educate the neighborhood (business or residential) about stormwater pollution, the storm drain system, and the watershed, and that provides information on alternatives such as recycling, household hazardous waste disposal, and safer products.

While it is generally recognized that the potential exists for hazardous household materials to come in contact with stormwater runoff, it is unclear at present how significant this source of contamination is. As such, it is difficult to quantify the benefits to water quality from household hazardous waste collection programs. However, such programs are a preventative, rather than curative, measure and may reduce the need for more elaborate treatment controls. Programs can be a combination of permanent collection centers, mobile collection centers, curbside collection, recycling, reuse, and source reduction. Public education is extremely important in implementing this BMP.

The two basic factors to be addressed during the implementation of a used oil recycling program are: 1) used oil collection, and 2) hauling/disposal. One commonly used oil collection alternative is a temporary "drop off" site on designated collection days. The public is notified that used oil can be brought to these specific locations and, if successful, a permanent site can be developed. Some communities rely solely on private collectors such a automobile service stations, quick oil change centers and auto parts stores to serve as collection sites. Well before oil collection commences, reliable local used oil haulers and recyclers should be contacted.

E-6. Cost Considerations

For these BMPs, volunteer work forces can be used to lower the program costs. However, collection and disposal can be very expensive and is partly a function of the frequency of collection, laboratory and detection equipment needed, required record keeping, facilities needed, and staffing.

F-1. BMP: Spill Prevention and Cleanup

F-2. Description

There are two major BMPs included in this category:

1. Vehicle Spill Control
2. Aboveground Tank Spill Control

The purpose of a vehicle spill control program is to prevent or reduce the discharge of pollutants to stormwater from vehicle leaks and spills by reducing the chance for spills by preventive maintenance, stopping the source of spills, containing and cleaning up spills, properly disposing of spill materials, and training employees.

Aboveground tank spill control programs prevent or reduce the discharge of pollutants to stormwater by installing safeguards against accidental releases, installing secondary containment, conducting regular inspections, and training employees in standard operating procedures and spill cleanup techniques.

F-3. Classification: Source/Non-Structural BMP

F-4. General Applicability and Experience with Technique Elsewhere

These two BMPs are receiving a lot of attention throughout the nation. Georgia Tech sponsors a continuing eduction program on leaking storage tanks which is well attended each year. The City of Seattle, Santa Clara Valley, Puget Sound Basin and municipalities throughout Texas are examples of areas developing such programs.

F-5. Additional Information

Major spills on roadways and other public areas are generally handled by highly trained Hazmat teams from local fire departments or environmental health departments. Major involvement of the municipalities is in the area of education and prevention.

Accidental releases of materials from aboveground liquid storage tanks present the potential for contaminating stormwater with many different pollutants. Materials spilled, leaked, or lost from tanks may accumulate in soils or on impervious surfaces and be carried away by stormwater runoff.

F-6. Cost Considerations

Prevention of leaks and spills is inexpensive. However, treatment and/or disposal of contaminated soil or water can be quite expensive. The cost for such programs may vary depending on the size of the program and needed facilities.

G-1. BMP: Dumping Controls

G-2. Description

This BMP addresses the implementation of measures to detect, correct, and enforce against illegal dumping of pollutants on streets and into the storm drain system, streams, and creeks.

G-3. Classification: Source/Non-Structural BMP

G-4. General Applicability and Experience with Technique Elsewhere

Municipalities are starting to develop dumping control programs in connection with EPA water quality requirements and NPDES permits.

G-5. Additional Information

Substances illegally dumped on streets and into the storm drain system and creeks include paints, used oil and other automotive fluids, construction debris, chemicals, fresh concrete, leaves, grass clippings, and pet wastes. All of these wastes can cause stormwater and receiving water quality problems as well as clog the storm sewer system itself.

G-6. Cost Considerations

The primary cost is for staff time required to detect and investigate illegal dumping violations, coordinate public education, and prosecution of offenders. Also the training of technical staff in identifying and documenting illegal dumping incidents is required.

H-1. BMP: Connection Controls

H-2. Description

There are three major BMPs included in this category:

1. Illicit Connection Prevention
2. Illicit Connection Detection and Removal
3. Leaking Sanitary Sewer Control

Illicit connection protection tries to prevent unwarranted physical connections to the storm drain system from sanitary sewers, floor drains, etc., through regulation, regular inspection, testing, and education. In addition, programs include implementation of control procedures for detection and removal of illegal connections from the storm drain conveyance system. Procedures include field screening, follow-up testing, and complaint investigation.

Leaking sanitary sewer control includes implementing control procedures for identifying, repairing, and remediating infiltration, inflow, and wet weather overflows from sanitary sewers into the storm drain conveyance system. Procedures include field screening, testing, and complaint investigation.

H-3. Classification: Source/Non-Structural BMP

H-4. General Applicability and Experience with Technique Elsewhere

The City of Fort Worth, Texas, Drainage Water Pollution Control Program is a good example. The program includes an "action" oriented program designed to monitor and correct non-stormwater discharges in urban storm drain systems using innovative screening, tracing and corrective techniques. Staff requirements are one full time equivalent per year (three part-time staff are utilized from other programs) for a total cost of $30,000. Equipment, supplies, and services range from $20,000 to $50,000 per year, depending upon the level of activity and co-

utilization of city services. Costs could be higher for initial startup and equipment purchases. This city also spends approximately $80,000 per year for their leaking sanitary sewer control program.

H-5. Additional Information

Control procedures for detection and removal of existing illegal connections tied to storm drain conveyance systems involve a multi-phased effort. Evidence of illegal connections is generally only detectable at storm drain outfall (end-of-pipe) locations. Therefore, the initial phase of source identification is through a field screening program, a sampling program, or a combination effort of both programs. A reactionary mechanism, based on citizens' complaint reporting, also serves as a preliminary identification of a potential illegal connection source. Secondary or follow-up phases of illegal connection identification require further investigations upgradient of pipelines or drainage ways to isolate illegal system tie-ins or discharges after tie-ins.

Illegal connections can occur in new as well as existing developments. Improper connections in areas of new development can be prevented through inspection and other verification techniques. The first measure to prevention is to make sure that existing municipal building and plumbing codes prohibit any unwarranted, non-permitted physical connections to the storm drain system. Building and plumbing code inspectors, in addition to new land development project inspectors, must visually inspect to ensure that illegal connections are not being physically tied to the storm conveyance system. Proper documentation and record keeping is essential to the function of such inspections. Documentation helps catalog the storm drain system and is required by Federal regulations. Visual inspection, however, is not a very reliable means of verifying the status of new physical connections and their final destination. Continued monitoring throughout the entire development phase would be necessary to guarantee the new physical connections between the sanitary sewers and storm drains had been prevented through the inspection process.

Public education programs will also aid in the monitoring of illegal connections and leaking sanitary sewers by making individuals aware of evidence of unwarranted discharges to the storm drain system. A community hotline for reporting such evidence can greatly supplement the stormwater department's field screening efforts.

H-6. Cost Considerations

Costs include staff and equipment for testing and inspection including verification of plumbing connections. Illegal connection location techniques and infiltration, inflow, and wet weather overflows from sanitary sewers can be labor and equipment intensive.

I-1. BMP: Street/Storm Drain Maintenance

I-2. Description

There are seven major BMPs included in this category:

1. Roadway Cleaning
2. Catch Basin Cleaning
3. Vegetation Controls
4. Storm Drain Flushing
5. Roadway/Bridge Maintenance
6. Detention/Infiltration Device Maintenance
7. Drainage Channel/Creek Maintenance

Roadway cleaning helps reduce the discharge of pollutants to stormwater from street surfaces by conducting cleaning on a regular basis. Catch basin cleaning on a regular basis also helps reduce pollutants in the storm drain system, reduces high pollutant concentrations during the first flush of storms, prevents clogging of the downstream conveyance system and restores the catch basin's sediment trapping capacity.

Vegetation control typically involves a combination of chemical (herbicide) application and mechanical methods. Mechanical vegetation control includes leaving existing vegetation, cutting less frequently, handcutting, planting low maintenance vegetation, mulching, collecting and properly disposing of clippings and cuttings, and the related training.

Storm drains can be "flushed" with water to suspend and remove deposited materials. Flushing is particularly beneficial for storm drain pipes with grades too flat to be self-cleansing. Flushing helps ensure pipes convey design flow and removes pollutants from the storm drain system.

Roadway/bridge maintenance is used to prevent or reduce the discharge of pollutants to stormwater from roadway and bridge maintenance by paving as little area as possible, designing bridges to collect and convey stormwater to proper locations, using measures to prevent runoff from entering the drainage system, properly disposing of maintenance wastes, and training employees.

Proper maintenance and siltation removal is required on both a routine and corrective basis to promote effective stormwater pollutant removal efficiency for wet and dry detention ponds and infiltration devices. Also, regularly removing illegally dumped items and material from storm drainage channels and creeks will reduce pollutant levels.

I-3. Classification: Source/Non-Structural BMP

I-4. General Applicability and Experience with Technique Elsewhere

In the City and County of San Francisco, ninety percent of the streets are swept at least once per week, and some sections are swept two to three times per week. San Francisco is also converting as much of its fleet as possible to vacuum sweepers. Many other municipal stormwater management programs have programs to maintain the drainage system and many are beginning to accept maintenance responsibility for detention facilities, infiltration systems, and the channels that make up the drainage system.

I-5. Additional Information

Given the costs involved with these BMPs, public education is needed to alert the public to the need for maintenance and the consequences of not developing maintenance programs. Regular maintenance of all portions of the drainage system is necessary to ensure the proper functioning of the system. Studies have indicated that detention basins may have a life as short as five years without maintenance. Lack of maintenance can also result in drainage and flooding problems which could result in significant damages and legal problems for the municipality. For the drainage system to operate as designed for both water quality protection and storm conveyance capacity, maintenance is essential. The public must become aware that everyone uses and benefits from the drainage system and all must share in the cost of maintenance.

I-6. Cost Considerations

Any municipal program designed to implement maintenance of stormwater management facilities and the channels within the drainage system, requires significant capital and operation and maintenance budgets. Initial costs for required equipment will be significant if the municipality has not done this type of maintenance in the past. Although costly, many municipalities are finding that unless some public maintenance of the drainage system is conducted, the system very quickly does not operate as designed and results in citizen complaints, drainage, flooding, and water quality problems.

J-1. BMP: Permanent Erosion Control

J-2. Description

There are three major BMPs included in this category:

1. Erosion Control - Permanent Vegetation
2. Erosion Control - Flow Control
3. Erosion Control - Channel Stabilization

Vegetation is a highly effective method for providing long-term, cost-effective erosion protection for a wide variety of conditions. It is primarily used to protect the soil surface from the impact of rain and the energy of the wind. Vegetation is also effective in reducing the velocity and sediment load in runoff sheet flow.

Flow controls address the reduction of erosion caused by runoff in the form of sheet flow. Sheet flow is defined as very shallow, widely dispersed flow which crosses the soil surface at velocities less than 5 feet per second. It normally occurs on gentle, uniform slopes with short (less than 100 feet) travel distance from the top of the drainage basin to the point of interest.

Channel stabilization addresses the problem of erosion due to concentrated flows. Concentrated flows occur in channels, swales, creeks, rivers and other water courses in which a substantial drainage area drains into a central point. Overland sheet flow begins to collect and concentrate in the form of rills and gullies after overland flow of as little as 100 feet. Erosion due to concentrated flow is typically extensive, causing large soil loss, undermining foundations and decreasing the flow capacity of watercourses.

J-3. Classification: Source/Non-Structural BMP

J-4. General Applicability and Experience with Technique Elsewhere

The states of North Carolina, South Carolina, Georgia and many others have enacted sediment control legislation which encourages the use of permanent vegetation for sediment control. Most erosion and sediment control programs also include flow controls and channel stabilization techniques.

J-5. Additional Information

Proper selection of ground cover is dependent on the type of soil, the time of year of planting, and the anticipated conditions to which the ground cover will be subjected. In addition, mulching is a form of erosion protection which is commonly used in conjunction with establishment of vegetation. It typically improves infiltration of water, reduces, runoff, holds seed, fertilizer and lime in place, retains soil moisture, helps maintain temperatures, aids in germination, retards erosion and helps establish plants in disturbed areas.

Once flow is allowed to concentrate, it is more difficult to control erosion problems. Thus every effort should be made to maintain sheet flow conditions for runoff. Where concentrated flows are unavoidable, the following techniques can be used to control erosion and resulting water quality problems:

- Rip Rap
- Gabions
- Check Dams
- Level Spreaders
- Armor Protection
- Diversions

J-6. Cost Considerations

The costs for the use of erosion control BMPs are normally associated with the municipal sediment and erosion control program. Thus the water quality benefits from controlling sediment and reducing pollutants to the drainage system are a byproduct of this effort without causing additional costs. Many of the costs are borne by the developers, although municipalities will occur some costs associated with administration, inspection, and enforcement of the program and associated regulations.

APPENDIX 5
THE ROLE OF STORMWATER MASTERPLANNING

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"Stormwater masterplanning" is a term which has come to mean a wide variety of things. In some municipalities a stormwater masterplan (SWMP) is nothing more than a collection of general specification drawings with some explanatory paragraphs as an introduction. In others it is a complex analysis of the total major and minor stormwater system including stormwater quality. In some locations masterplans address existing problems while in some they seek to anticipate, and avoid, future problems. Following are some examples.

- .In Nashville, Tennessee a SWMP was developed to correct known and future major creek flooding problems.
- In Atlanta, Georgia a SWMP was conceived as a very detailed set of plans and specification drawings designed to correct known flooding problems.
- In a Virginia SWMP planners and engineers defined in broad qualitative terms environmental quality activities necessary to bring a certain stream basin to a pre-determined level of water quality and aesthetic goals.
- In Mecklenburg County, North Carolina a multi-criterion masterplan was developed to address, through a series of layers, stormwater quantity, quality, erosion and opportunities for multi-objective use of major drainage systems.
- In Raleigh, North Carolina a plan envisioned corrections to stormwater quality problems to save a lake resource.
- In Santa Clara County, California a comprehensive plan for the reduction of both point and non-point source pollution was developed.

Stormwater masterplanning plays a key role in identifying existing and future problems, opportunities for enhancement of stormwater use, cost estimates, impact assessment and assigning priorities for change and improvement.

THE MASTERPLANNING PROCESS

The discussion below defines a generic process which should be followed by any masterplanner. The process moves through a thorough needs and goals analysis which assesses all physical problems to be addressed by the masterplan and uncovers root causes. The masterplanning process then moves, in turn, through identifying constraints to possible solutions and formation of an appropriate technical approach to find useful solutions.

Step 1: Make A Needs Analysis

The first step in any masterplan is to gain a clear understanding of the actual needs and goals of the municipality. There is an old axiom of sales that states that the customer never tells you what he really needs but what he thinks he needs. That is never more true than in stormwater masterplanning. To gain a clear understanding of the real needs a logical and ordered approach must be followed.

The term "stormwater planning" means different things to different people. To the municipal administrator it often means a drainage study to "solve Mrs. Smith's backyard flooding". It might mean "floodplain management" to the community FEMA representative; or "water quality enhancement" to the environmentalist. Whatever its meaning or eventual activities, an ordered understanding of its various components is essential to proper control of stormwater.

A typical program begins when a particular problem becomes apparent. Usually it is flooding, erosion, water quality and/or drainage infrastructure problems. The solution normally is to fix the individual problem. However, a "quick fix" solution to the apparent problem is rarely a permanent solution because it rarely addresses the underlying issues and root causes.

Goals and objectives of the masterplan should be carefully determined or disappointment will invariably result. A masterplan is not a magic box out of which instant solutions are pulled. Most problems took a long time to develop and will not be fixed overnight. This becomes even more true as the planner deals with erosion and non-point source pollution problems.

The deliverable product should also be defined. Often masterplans gather dust on the shelf as implementation funds are sought. When the time comes to actually build the projects the information may be out of date as zoning changes and new development have changed the situation. A masterplan should be a dynamic document tied to a mathematical model where appropriate and that model kept up-to-date periodically. This can be done quite easily through modern technology which ties mathematical models to geographic information systems (GIS) and CADD systems. As changes occur in the field they are registered in the database. The model is automatically updated and run when appropriate. In this way masterplanning is done "on the fly" as development occurs, changes from assumed conditions are made (there will always be changes) or budgets are modified.

Step 2 : Determine Constraints To Possible Solutions

There will always be constraints to solutions to problems. Masterplans must be realistic. Expensive structural solutions to flooding problems cannot often be afforded. Key pieces of property may not be available and the political will may not be there to condemn land even if it is vital to flooding abatement.

Constraints to any possible solutions fall naturally into major categories.

- Technical constraints - to any solution might include lack of necessary data. This is often the case for stream flow and almost always the case for water quality studies. Another technical constraint may be the ability of the municipal staff to use the tools developed. It makes no sense to recommend a complex watershed model if no one on the staff will be able to keep the model up-to-date after the departure of some consultant.

- Political constraints - are often the most important to the would be masterplanner. Some solutions have failed in the past with embarrassing consequences to a political supporter of that approach. The planner should think twice before recommending this approach

again even if it is superior. For example, impact fees may have a very bad reputation in some parts of the country where they have been successfully challenged in court. Detention dams (or "dry dams" as the Corps of Engineers calls them) have a very bad reputation in some municipalities where maintenance has proven to be costly. A sense of the political will power is necessary to configure solutions which will be acceptable. This must be tempered with the fact that political climate statements are perceptual factors and often depend on who is making the statement of "fact". Also, political statements will change often: with each election, after a crisis, when a new regulation impacts stormwater, during budget discussions, etc.

- Social constraints - reflect the values of a given community. For example, channel modification may be seen by a certain municipality as anti-environmental and not allowed. Wetlands may be seen as either a very positive environmental amenity or as a waste of valuable development land depending often on the economic condition of the community. Some parts of some municipalities may be "off limits" for location of detention facilities or for investing scarce resources.

- Physical constraints - can be such things as soil type, topography, moisture, bedrock, etc. Physical constraints might also include the availability of materials such as sand or riprap. Urban development may constrain certain solutions due to the presence of structures or roads.

- Legal constraints - reflect local, state and federal restrictions of masterplanning options. Legal constraints are often environmental in nature, such as the necessity of obtaining permits for activities in a stream. Some municipalities are constrained by state law from exercising very many powers while "home rule" states have given strong powers to local municipalities. General case law and perceived liability may restrain municipalities from certain options for fear of a lawsuit or a ruling of a "taking" of property. Legal boundaries may also constrain some types of solutions that cross outside municipal limits.

- Financial constraints - almost always limit, to some extent, the types of solutions that are possible. While not all studies are assessed on a strict "benefit-cost" basis, most projects have to give the perception that they are worth the expense, both initial and ongoing. Budgets for the masterplan also usually limits the type of analysis and level of detail. Sometimes suitable options exist, though a "wild guess" at the front end of a study does not justify rigorous analysis of data based on that guess, later in the study. This is often the case with detailed reliance on hydrology developed from little or no data.

Step 3: Formulate The Technical Approach

As stated in the beginning, the term "masterplan" can mean almost anything. When considered herein the term will deal with the technical approach to stormwater solutions over a certain area or in a certain drainage system. This will eliminate the primarily institutional approaches to masterplanning where ordinances or financing studies predominate.

A masterplan can concentrate on:

- the major drainage system and/or the minor system,
- quantity and/or quality and erosion control,
- existing and/or future conditions,
- urban and/or rural systems,
- correcting problems and/or planning to avoid problems,
- "soft" solutions and/or "hard" solutions, or
- individual solutions and/or systems analysis.

The goals of the masterplan study determine the level of effort and detail involved, as well as the degree of conservatism built into flow estimates. Flood hazard studies may require only an estimate of peak flows. Other studies may require the development of design stormwater runoff hydrographs and the timing of these hydrographs with respect to each other. There are varying complexity of studies and often studies are done in phases.

For example, studies involving flooding generally fall into three categories. The categories build on one another with the final phase being the design and construction phase.

1. Flood Hazard Potential Studies - These studies provide flood hazard information for certain frequency floods (for example, identification of the 100-year return period flood elevations for definition of FEMA required floodplains and floodways). Studies vary significantly in scope and complexity. The end product of a flood hazard potential study is the ability to determine, within an acceptable level of accuracy, both the flooding elevation (stage) and the probability of occurrence of a flood (frequency) at points along a stream. This can be done for both existing and future conditions. Measured or transferred data are extremely valuable for accurate flood hazard potential studies. This includes coincident rainfall-runoff records, high water marks, and long term flow records. The stage-frequency relationship is developed from a combination of a stage-discharge curve (rating curve) at a reach developed through hydraulic analysis and a discharge-frequency curve, developed from a stream gage or synthetically through regression analysis.

2. Planning Studies - Information from flood hazard potential studies is used to develop economic evaluations and/or environmental impacts. Examples would be feasibility evaluations of structural or non-structural flood control alternatives or impact evaluations of alternate land use patterns. A stage-damage curve is usually developed for points of interest through the use of property surveys. The stage-damage curve shows what dollar amount of damages which would be expected from a flood of a certain elevation. If the frequency of certain flood levels are also known from the flood hazard potential study, an average annual damage estimate can be made and used as a tool to evaluate and compare various proposed alternatives.

3. Design Studies - These studies use flood flow frequency information in the design of flood control structures, culverts, bridges, levees, detention facilities, etc. Non-structural

designs seek to mitigate the effects of a flood, while structural designs seek to alter flood events. Designs move through sketch plans, preliminary planning, design, and plans and specifications.

TYPICAL MASTERPLAN TYPES

Even though there are an infinite number of possible detailed approaches to masterplanning there are some general categories of approach or typical types of plans that can be described.

Major Creek Flooding

This type of masterplan seeks to correct out-of-bank flooding from major creek systems. Typically, these are the creeks that have been studied under the Federal Flood Insurance Program, though often the study continues upstream to a point where intermittent stream flow begins (blue line on a typical USGS Quad map). Flood elevation is often key so that a backwater profile is necessary, though often the FEMA study can be used for lower budget studies. Benefit-cost analysis is often of importance since the magnitude of flooding is usually great and the cost for mitigation equally great.

Major creek flooding masterplans begin by locating flooding areas and by a determination of information about the flooding such as: depth, frequency, expected annual damages, types of structures, velocities, directly contributing areas, channel characteristics, etc. Usually a combination of alternatives is found to be effective in reducing flooding. Often a frequency such as the 25-year flood is used for alternative development since this frequency normally deals with the most cost effective frequencies for major creek flood problems. Though floods of 100-year or greater return period are used for locating floodplain boundaries for safety purposes. Two-dimensional modeling may be necessary for very wide and flat floodplain areas where velocities and more exact flood heights are necessary. Unsteady flow modeling may be necessary for calculation of flood waves such as may occur during a dam break situation or in steeply sloping terrain.

Structural alternatives such as: levees and floodwalls, reduced roughness, channelization, cutoffs, diversions, detention and retention, etc., are assessed in combination with non-structural measures. Concern for the environment and for stable channel design should be in the forefront.

Erosion control design often is based on the 2-year flood since this is the approximate frequency of bankfull flows for most channels which have not been altered by man. Environmental enhancement or mitigation measures include such things as: high or low flow channels, clearing one side only, artificial meanders, artificial wetlands, in-stream habitat structures, etc.

Development, land use, and flood control decisions are often made on the basis of benefit-cost analysis, though this requires first floor elevations and detailed elevation-damage curves. There are approximate methods which will yield accurate answers putting solutions in rank order and approximate absolute ratio values. Often decisions depend on hard-to-quantify features such as integration of a solution site with such things as parks, greenways or other recreational areas.

After objectives and constraints of the plan are obtained typical technical analysis steps include:

- data collection,
- preliminary field investigation,
- design storm development,
- hydrologic model development,
- hydraulic model development, and
- system alternatives development and analysis.

1. Data Collection - This phase determines all available information and ascertains field conditions. Sub-steps include the following:

- Review of available documents from U. S. Geological Survey, Corps of Engineers, Soil Conservation Service, FEMA, other Federal and State Offices, local records, miscellaneous studies, etc. Determine degree and location of urban development over time from zoning records, annexation records, plat recordings, or other local records and knowledge.

- Obtain historic flow information including discharge-frequency relationships, historic high water marks, rainfall records, stage-discharge relationships, bridge designs, known cross sections, mapping, etc. Determine whether transfer of information is a viable solution.

- Plan hydrologic study. Delineate preliminary sub-basins and routing reaches and structures for hydrologic study.

- Plan hydraulic study. Locate existing or new cross sections and modelled structures for backwater analysis on maps.

2. Preliminary Field Investigation - This phase estimates all hydrologic and hydraulic parameters in the field as well as identifying unusual conditions. Typical sub-steps include the following:

- Make field estimates of all hydrologic and hydraulic parameters such as roughness coefficients, bridge openings, culvert sizes and inlet types, overtopping circumstances, flooded structure locations, etc.

- Perform a field investigation to ascertain conditions which may impact runoff or hydraulic parameters such as ponding and reservoirs, undersized crossings, debris barriers, recent erosion, new development, channelization, location of wetlands or other environmentally sensitive areas, etc.

- Interview local agencies, residents, review newspaper files for historic high water marks or rainfall information, etc.

- Take pictures of all unusual situations with measurable scale in picture.

- Finalize cross section locations, overflow bypass pathways, and sub-basin boundaries. Measure cross sections with hand level and tape or mark survey points if necessary.

3. Design Storm Selection - The design storm(s) to be used for masterplan development must be selected which will provide adequate protection for local residents and are reasonable for development purposes.

4. Hydrologic Model Selection - It will be important to select a hydrologic model which accurately estimates hydrologic values for the local area, is adequate to develop hydrologic estimates for the masterplan, and can be used by city personnel and local consultants to implement the masterplan and update the plan as future development occurs.

5. Hydraulic Model Selection - Masterplanning deals with the interaction of many different land uses within the watershed. Thus it is important to select a model that can combine hydrographs from different locations within the watershed and route the hydrographs through what is often a complex network of channels, pipes and storage facilities within the drainage system. Also the model must be capable of estimating flood elevations at different locations within the watershed.

6. System Alternatives Development and Analysis - There are many methods for developing an analysis scheme for the watershed. The actual procedure chosen depends on the problems identified. Brainstorming meetings are particularly effective if solutions are not limited to conventional channel improvements or detention.

After a preliminary assessment of the situation and possible solutions identified on available maps, make field reconnaissance of known flooding or erosion locations taking note of types of structures, relative worth, out buildings, fences, etc. Look for evidence of geomorphic adjustments of the channel in terms of widening, deepening, large movement of sediment, lateral instability, headcutting in the main channel or tributaries, indications from tree shape and size, etc. Look for evidence of debris problems, structural failure of conveyance or crossing structures.

Assess the physical possibility of different types of structural solutions such as channel widening or deepening, levees, possible reservoir or detention locations, high flow channels, diversions, pumping, etc. Assess non-structural solutions such as home raising or moving, flood proofing, flood warning, etc. Checking the timing of hydrographs may reveal other locations for reservoirs which provide indirect peak flow reduction from a side tributary.

After screening likely alternatives modify model for each feasible alternative. Modify outflow-storage relationship for reservoirs and hydraulic geometry for channel adjustments. Various combinations of alternatives may serve to enhance any one used alone. Look for opportunities to integrate solutions into the character of the neighborhood or area. Tennis courts and soccer and baseball fields have been used for detention ponds. Greenways, walkways and linear bike trails work well for floodplain areas. Wetlands can make wonderful strolling areas if boardwalks are provided.

Minor System Flooding

The minor or "convenience" system is often designed to the 10-year or even more frequent flood. This system is often overwhelmed by intense thundershowers. Although any one site may not be overwhelmed on the average more often than the design frequency, there may be many such flood events in a major urban area over a design frequency time span.

The approach to minor system masterplans is to identify and attempt to quantify flooding problems. To do so this often requires a concerted effort to involve local residents and political leaders. Often a "problem" is not anything more than an inconvenience. Therefore, it is important to determine the design policy and performance level-of-service of the Municipality and prioritize problems based on a professionally driven evaluation system such as: life and health, residential structural damage, non-residential structural damage, utility damage and nuisance.

Quantifying these problems involves use of a simple methodology for peak (or sometimes whole hydrograph) flow estimation and a determination of whether the problem is isolated or part of a system-wide deficiency. It is important not to simply pass the problem downstream to the next undersized structure. Solutions are normally straight forward and cost and materials estimates are often included.

Data collection and analysis can be very time consuming and expensive. It is often not worth the expense to analyze the whole of a municipality system. If the system is old it has probably been tested above its performance capabilities. If an effective complaints system is in existence those complaints should be the source of determining which parts of the system are analyzed in any detail. Simply because a system backs water up does not constitute a problem per se. It is actually advantageous to store runoff throughout the system in planned locations both for economic reasons having to do with pipe size and for pollution and erosion reduction reasons.

Pre-Development Planning

This type of a study involves not only the correction of problems but the search for land development alternatives to avoid problems in the future and to enhance the stormwater resources of a region. There are a number of ways to go about such a study but they typically involve an estimation of both existing and future flows. Often, more than one future land use development alternative is used. Hydrologic studies are the norm. Much of the process is similar to the major system flood study except alternative solutions have a great deal of flexibility and multi-objective planning plays a greater role.

An example of such a study will illustrate the approach. Masterplans were developed for Mecklenburg County, North Carolina. The masterplanning effort followed the typical three step approach: (1) identify the needs, goals and opportunities; (2) identify and explore constraints on the possible solutions; and (3) develop and execute a set of objectives and an overall technical approach. Step one variables included: major and minor channel flooding and erosion, water quality degradation due to urban runoff, undersized stream crossings, recreational area locations,

floodplain management strategies and enhancement locations. A number of political, social, financial and technical constraints were identified and methods developed to incorporate all concerns.

The technical approach consisted of the development of a system of computer-generated overlays using customized software and existing land use conditions and ultimate development conditions for hydrologic modeling. To assist in the location of areas in each of the watersheds where multi-objective needs, goals and opportunities could be met, a series of overlays were developed depicting: all of the problem location variables listed above, critical flora and fauna, historical and cultural locations, parks and recreation locations, planned greenways, wetlands, planned land use conflicts, transportation arteries existing and planned, planned and existing intense development areas, existing water features and suitable topography.

Based on these variables, a number of possible locations were identified where planned facilities or non-structural efforts should concentrate. Each suitable site was then checked against soil suitability, land ownership, utilities and specific environmental concerns. Locations and site-specific approaches were developed, costs estimated and alternatives placed in a priority list for consideration. The second phase of the plan is the actual design and construction of key facilities.

Stormwater Quality Study

There are some factors which may mitigate against performing detailed stormwater quality modeling:

- The state-of-the-art in stormwater quality modeling is approximate even with available data.
- The availability and quality of existing data for most areas is poor.
- It is often difficult to ascertain cause and affect in surface runoff pollution cases, especially if chemical interaction is of concern.
- Methods for treating surface water pollution problems even if they are well known and quantified are often only marginally effective and expensive to build and maintain.
- Most water quality requirements do not involve modeling but a simple design standard (such as capture of the first half-inch of runoff).

Despite these drawbacks stormwater quality modeling is often done on a site specific or watershed scale. Stormwater quality masterplanning is mandated under the 1987 Water Quality Act and implementing regulations for new developments or significant redevelopments. In the future, as the knowledge of the cause and effect of receiving water pollution impacts grow and the knowledge of its mitigation increase surface quality modeling will grow in prominence. Water

quality modeling is most useful and effective when there are specific pollutants of concern and known impacts on receiving waters are to be mitigated.

The objectives of a typical water quality study are:

- characterize the urban runoff;
- provide input to receiving water analysis;
- determine effects, sizes and combinations of control options;
- perform frequency analysis on quality parameters; and
- provide input to cost-benefit analysis.

A water quality study normally includes or concentrates on the reduction of surface water pollution to some receiving water. Storms of interest are less than the 2-year storm since the vast majority of the pollution comes from the many minor storms rather than the few major ones. Often the study must take into account requirements of the 1987 Water Quality Act.

Pollution impacts are both acute (short term) and chronic (long term). The response time for pollution impacts in lakes and bays is in the order of weeks to years. However, for the type of ponds and streams commonly encountered in urban runoff the response time for such constituents as dissolved oxygen, bacteria, sediment or nitrogen is in the order of hours or, at most, days. Statistical or regression based models are simple to apply and require little calibration. Physically based models have more flexibility in application, can generate pollutographs for single storms more effectively, and can be extended for "what if" analysis with more confidence.

Sometimes modeling of concentrations and impacts is not strictly necessary. In many cases the inability to show or quantify direct environmental impairment from stormwater runoff makes the development of designs to mitigate some specific impairment difficult to quantify or justify. Typically the solution to the cause-effect dilemma is to take one or more steps back from the specific impairment or degradation issue and determine stormwater quality masterplan features based on: (1) a numerical chemical water quality standard or designated use basis; (2) a biological indicator or assessment standard; or most commonly (3) on a design criteria basis where Best Management Practice (BMP) designs must meet some simple standard (for example, capture and treatment of the first half-inch of excess rainfall). If these simplifying steps are appropriate then detailed water quality modeling to determine cause and effect is not necessary and simple estimates of annual or single storm pollution loadings are all that is required. In these cases a simple loading model is developed and BMPs placed within the watershed to reduce these loadings to some target values or percentages. In many cases stormwater or receiving stream sampling in support of the study or to guide its ultimate application and measure its effectiveness is desirable.

There are then a number of variations of stormwater quality masterplans depending on the results and problems.

- If protection of a lake, bay or estuary is the main objective, long term loading estimates and impact assessment is normally done. An attempt is made to link these loadings to

land use. In these cases a lake or estuary model is applied in conjunction with the loading estimates to determine long term impacts of loadings. Base flow loadings are also important in these types of studies with concentration values taken from sampling or standard figures for the region. Alternative land use or development controls are assessed in conjunction with structural or non-structural BMPs. Typical of this type of study is a plan to protect a drinking water supply from the impacts of urban development or agricultural practices.

- If estimations of pollutant thresholds, concentrations and frequencies in either runoff or receiving waters are of concern the most effective modeling will generate pollutographs for individual storms or run a continuous simulation for a period to estimate pollutant removal efficiencies of structural BMPs.

- If the design of BMPs to meet a simple annual loading reduction target or design criteria is appropriate then simple event mean concentration based annual loading methods can be effective if estimates of pollution reduction for BMP designs can be made. In these cases annual or seasonal loadings are estimated based on rainfall and runoff volumes. Often these are tied to land use both for runoff volume and event mean concentrations of pollutants. Then locations for effective placement of regional or site BMP controls are found and assessed. Solutions include land use controls, regional BMPs, site development restrictions or design criteria, or other programmatic BMPs such as street sweeping, limitations on herbicide or pesticide usage, maintenance practices, etc. This is probably the most common kind of study performed by the non-specialist in stormwater quality modeling.

BMPs are designed or developed to treat pollution "problems" with either target percent reductions or determinations of the "maximum extent practicable" for reduction based on various possible combinations of BMPs. Both structural and non-structural BMPs are used. Non-structural BMPs are sometimes all that is possible in highly urbanized areas with little room left for structural solutions. Regional structural treatment is often most cost effective and provides the greatest assurance for a long term commitment to maintenance. Usually rules of thumb can be developed for first phase screening analysis of possible sites for structures using such things as available volume per acre treated or pond surface area related to drainage area.

LIMITATIONS OF MASTERPLANS

As important as masterplans are to any comprehensive stormwater program, by themselves they will not solve problems or prevent flooding, drainage or water quality problems. The masterplans represents a blue print for action that must be taken if these problems are to be solved or prevented. To often people see the masterplan as the end product and forget that if the plans are not implemented little good will result from the completed work.

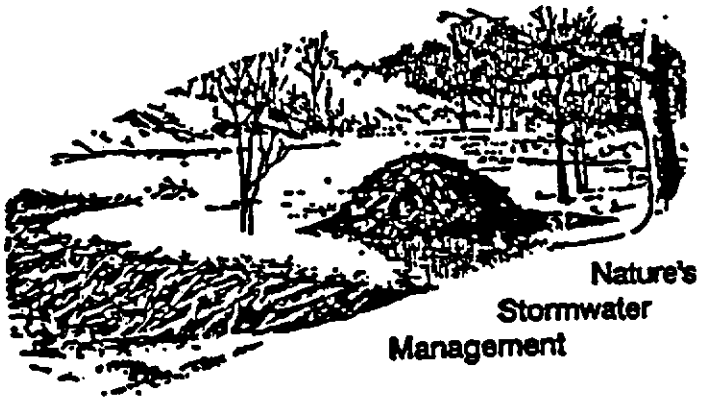
Each masterplan is undertaken in response to specific problems, goals, policies, etc., that relate to the watershed being planned and the implementation tools available. Detailed plans which analyze hydrologic-hydraulic and water quality parameters to a very small scale, say 10 to 20

acres will be more expensive to develop than more general plans which only analyze down to say several hundred acres. However as a consequence, more general plans will not address flooding and drainage problems associated with small developments and single lots. Thus many of the limitations of any masterplan will be related to the scale used for plan development and engineering analysis.

Other factors that may influence the limitations of specific masterplans include data available for plan development, political acceptance of the final plan, acceptance and enforcement of the plan by local citizens and professional groups, and available funding. In addition, keeping the plan up-to-date is very important if the plan is to remain a viable tool in dealing with stormwater management problems. The plan should not become a static document but rather it should be a part of a dynamic stormwater management program that changes as the problems and local circumstances change.

APPENDIX 6
LETTERS FROM MR. EARL SHAVER AND MR. ERIC LIVINGSTON

Fax Transmission



To: Jon Jones
Wright Water Engineers

From: Earl Shaver
Human Being

Date: September 22, 1994

Re: Fulbright Spring Protection Study

Number of Pages: 4 (including this sheet)

I am responding to your request for comments on the Fulbright Spring/South Dry Sac Basin Project. My comments are based on very little "watershed specific" information such as topography, soils, existing and proposed land use, etc., so some (hopefully not most) of my comments may not be applicable.

You requested comments on the following land use tools:

zoning
ordinances
impervious area limitations
slope limitations
structural BMP's

The information transmitted to me, other than your letter, included the Request for Consultant Qualifications. There are some key areas discussed in that document that I thought should be emphasized in terms of my comments.

1. They want an "overlay district" to protect important resources.
2. Bacteria and nitrates are the most common potential NPS pollutants in the study area.
3. With urbanization, water quality deterioration is expected due to sewage effluent, urban runoff, and leaks, spills, and discharges from commercial and industrial facilities.
4. Potential point sources include landfills, manufacturing plants, and hydrocarbon related facilities.
5. Heavy sediment loads are carried quickly through the surface and subsurface systems. Fulbright Spring may be shut down periodically during these times, as it was during construction of the Sac Trunk Sewer construction.
6. Faulting and displacement of formations in this area could allow water and contaminants to migrate into the deeper aquifer.
7. The clays formed from the northwest have high shrink-swell potential.
8. Relatively flat or gentle slopes exist in the area. Some of the soils contain sink holes.
9. It is a very complex hydrologic system.
10. Many springs in the County receive effluent from septic systems.
11. The Little Sac Trunk Sewer will allow urbanization to proceed rapidly in the central and

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eastern portion of the recharge area.

12. Road salting is a problem at Sander Spring.
13. There are two primary issues - flooding and water quality. Local standards and design techniques address the flooding issue.
14. They are concerned about sediment from construction sites; organics; heavy metals (gravity disadvantaged metals), nutrients, and bacteria.
15. The volume of runoff renders traditional end of pipe treatment ineffective, so source controls and BMP's are necessary.

My thoughts on this effort include the following items:

1. There has to be a combination of strategies to provide for effective protection of the resources. The strategies should include land use, pollution prevention, education, prioritization of BMP's, effective implementation of an erosion and sediment control program, effective implementation of a stormwater management program, an effective on site disposal system program, and adequate funding of all these efforts. I want to provide some detail on the various strategies.

Land Use

I don't have a lot to add regarding land use and sinkholes as I have not been confronted with extensive limestone problems in either Maryland or Delaware. One suggestion that I would make relates to impervious areas. Traditional approaches to land development need to be reconsidered with respect to directly connected impervious areas. The County should consider flexibility on the requirement for curbs and gutters and enclosed storm drain systems. One additional consideration that we have been working on in Delaware relates to road width. Reducing the width of residential roads could have a significant impact on the total volume and rate of stormwater runoff. One subdivision in Delaware reduced its road impervious area acreage by 20% by reducing the width of the interior roads. The main culpret here is the fire departments who want wider road widths to allow for greater manuverability of fire trucks. Reducing the road widths in conjunction with using loop roads rather than cul-de-sacs met their concerns.

Two additional land use issues that have been addressed here relate to steep slope limitations and aquifer recharge areas. Through groundwater studies, principal recharge areas have been located in one county and development in those areas must use infiltration practices to maintain the recharge of the local aquifers. Stormwater runoff from pollutant generating sources does not go into the infiltration structures but is treated through conventional practices such as ponds. Roof areas, generally considered cleaner than parking lots, have their runoff directed to dry wells or infiltration basins to maintain recharge rates.

There is another program that addresses steep slope development. The county has passed an ordinance prohibiting development on slopes in excess of 20%. The ability to control erosion on these steep slopes in conjunction with problems related to permanent site stability were the basis for the limitation. Let me know if you need additional information.

Pollution Prevention

There was discussion regarding the potential impact of commercial or industrial discharge into the spring recharge areas. The county can use the existing authority of the NPDES stormwater program to require appropriate industries to prepare and implement a pollution prevention

program. The county should work with the State NPDES authority over proper procedures. Under the freedom of information act, the county has the right to visit industries (probably with a state representative) to ensure implementation of pollution prevention activities and practices.

Education

As you are aware, I am a proponent of education in all aspects of program implementation. Pamphlets and educational materials should be made available to all property owners regarding their responsibility towards pollution reduction. Lawn fertilizers, pesticides, waste product disposal, septic tank maintenance, etc. are all areas where everyone has to participate if protection of the Springs is to be successful. Automotive waste products should be properly disposed of. The county should establish recycling centers or days of the week where home pick up of waste products can be done. These centers or pick up areas have to be easily accessable if people are going to use them. Another popular educational effort relates to storm drain labeling. Some slogan of local interest could be developed and scout troops, school classes, etc. can be used to implement the effort. Educational efforts also must be directed towards developers, consultants, inspectors, contractors, etc.

Design Guidance

In terms of development, redevelopment, or retrofitting, design guidance has to be provided to the consultant and developer. Those practices which may provide the most benefit should be recommended over other practices whose implementation may be questionable. In terms of stormwater treatment, ponds may well be the practice of choice due to concern over sinkholes. I would recommend constructed wetlands since bacteria and nutrients are of major concern. An individual geologic analysis must be made on a case-by-case basis on the need for a pond liner (geotextile or clay) to avoid possible sinkholes. Infiltration practices can also be considered on a case-by-case basis depending on soils analyses, and they might be used for roof runoff only. The county may want to prepare a map which presents areas where certain practices need to be implemented or avoided depending on soil and bedrock conditions.

I have also become a salesman for the use of filtration systems such as sand filters. These practices are very appropriate for "ultra-urban" sites where other conventional practices are not appropriate.

Erosion and Sediment Control

There appears to be considerable concern over the need to provide effective site control during construction. Any effort to protect the springs must include the implementation of an erosion and sediment control program. This program must be adequately funded and staffed if it is to be successful. A good erosion and sediment control handbook must be used along with guidance in terms of stabilization and phasing of projects. The foundation for this effort rests on adequate legal and regulatory authority. There needs to be minimum standards which must be adherred to and penalty provisions which come into play in the event of non-compliance.

The implementation of an erosion and sediment control program is essential if the quality of the springs is to be maintained. The downstream impacts of site erosion can be severe and the county must make a clear commitment to the program if efforts are to be successful. A recent study of erosion and sediment control programs around the country indicates that the principal reason for poor implementation rests on inadequate funding, staffing, and political support. These items must be considered in the county's initial consideration of strategies. Failure to

implement this component may make the rest of the efforts ineffective.

Stormwater Management

In a similar fashion to erosion and sediment control, the county must implement an aggressive stormwater management program. The program must also have a solid foundation in terms of legal authority, staffing, and funding. Design guidance must be provided to consultants and land developers in addition to workshops on proper design. I would suggest that the county have preferred practices in specific locations rather than to use a "cook book" of practices from which the consultant and land developer can choose from. Stormwater practices are not created equal in terms of their pollution reduction ability, and certain practices are more appropriate in areas where they can be effectively used, or certain practices are more effective at treating expected pollutants from specific land use.

On Site Disposal Systems

While it is understood that public sewer will be available for most of the watershed, on site disposal systems will still be used in certain areas where sewer is not available. I would recommend that systems be required whose design enhances nutrient and bacteria reductions. Most conventional on site disposal systems pollute groundwater as they are placed below the soil profile into parent material. The use of mound systems would provide a level of protection in terms of nutrients and bacteria.

Funding

The county is going to have to implement a lot of different strategies if the goal of water supply protection is to be realized. All of these efforts rest on an adequate and permanent source of funding. The most effective mechanism, at this time, would be the implementation of a stormwater utility. Some of the most effective programs around the country in terms of implementation are funded through a stormwater utility. Another approach which appears effective is an advelorum tax placed on the residents of a county at large. These programs should not rely on federal funding (initial items only - such as storm drain stenciling, design handbooks, demonstration projects), permit fees (can be a component but not relied on), or yearly appropriations by the local governing body (this makes the yearly budget decision based on political whims). If the county cannot develop an effective long-term funding mechanism, all of the eloquent dreams discussed in reports are meaningless.

2. There was little discussion of any need to maintain existing groundwater recharge levels. Should there be any concern about not reducing the existing sources of water to the springs? If recharge is considered to be important, it must be considered carefully due to sinkhole potential and potential for groundwater quality impacts.

Please understand that these comments are only cursury, at best, as time allocations were to be kept to a minimum. Let me know if any clarification or expansion is needed.

October 8, 1994

Mr. Jonathan E. Jones
Wright Water Engineers, Inc.
2490 West 26th Avenue, Suite 100 A
Denver, Colorado 80211

Re: Fulbright Spring Protection Study

Dear Jonathan:

Thank you for allowing Earl Shaver and I, through the Watershed Management Institute, to participate in this project. The Watershed Committee of the Ozarks, the City of Springfield, and Greene County face was of the greatest challenges in watershed management - protection of ground water/spring quality and flow within a karstic watershed. It is very important for these entities to understand that structural BMPs simply are tools to partially mitigate the hydrological and environmental effects associated with urbanization, AND that our current structural stormwater treatment and management practices are rather ineffective. The only solution to this dilemma is through a comprehensive watershed management program which first emphasizes pollution prevention and then considers pollution mitigation. Accordingly, it is nonstructural controls, especially sound land use planning, management, and implementation which is the key to successfully accomplishing the goal of this project. Of course, successful execution of this approach requires a solid institutional framework and reliable funding sources. The final essential piece of this puzzle is the use, with proper operation and maintenance, of effective stormwater treatment and management systems.

As a general source of information on these topics I call your attention to our latest publication, Fundamentals of Urban Runoff Management: Technical and Institutional Issues, a copy of which was sent to you by Earl. In particular, Chapters 7 and 8 provide information on erosion, sediment, and stormwater management practices; Chapter 12 summarizes nonstructural practices; while Chapters 10, 11, 13, and 15 present information about institutional aspects of watershed management. In my accompanying comments I have focused on key aspects of each of the three components discussed above. For example, I have included information on our design and operational guidelines for stormwater treatment systems used in karst areas. I also have enclosed a copy of the Tallahassee Environmental Management Act which integrates stormwater management, tree and natural area protection, and landscaping requirements, along with the Leon County Aquifer Protection Ordinance.

If you have any questions or need additional information, please let me know.

Sincerely,

Eric H. Livingston

Eric H. Livingston

FULBRIGHT SPRING PROTECTION STUDY

I. GOALS OF THE PROJECT

Before one can address the "hows", sound goals must be established. Based on the project's RFP and my experience with this type of development in Florida, I think that it is extremely important that urbanization in the watershed meet the following performance goals:

- Nondegradation of the ground water and springs
- Minimum alteration of the watershed's water budget, especially with respect to recharge volume, soil and depressional storage, and runoff.
- On each site the post-development stormwater peak discharge rate, volume, and pollutant loading will be no greater than pre-development levels.
- Minimize the amount of imperviousness, especially the amount of directly connected impervious area.
- Promote "natural" landscaping to reduce the need for yard fertilization, pesticides, and watering.

These performance goals will help to assure that the area's recharge capacity, spring flow, and ground water quality are not adversely affected by the watershed's urbanization.

II. NONSTRUCTURAL MANAGEMENT PRACTICES

Because of the vulnerability of the ground water and associated springs within the Fulbright Spring/South Dry Sac Basin, the two keys to protecting this resource are sound land use planning and implementation, along with public education. The area's soils and geology create this vulnerability and the inherent limitations (carrying capacity) posed by these terrestrial resources with respect to intensive development must be recognized. Unfortunately, more often than not, the public, elected officials, and resource managers do not want to recognize these limitations, address the problems created by them, nor discuss alternative land management. I can assure you through experience here in Florida that even with our sound land use planning and management programs and our stormwater treatment requirements, we have still degraded similar ground water/spring resources because of a lack of commitment to addressing the difficult questions posed by urbanization in very sensitive areas.

To use all of the nonstructural BMPs available, it is recommended that a geographic information system be used for the development and implementation of the watershed plan. Not only can this provide a very cost-effective manner of evaluating different land use scenarios but it can also be used to track implementation and even schedule future maintenance inspections of septic tanks or stormwater treatment systems.

1. SITE EVALUATION

A complete site evaluation needs to be completed for the study area. Maps of the area's vegetation, topography, soils, water bodies, sinkholes, natural depressions, faults, and other

known geologic information are essential. The purpose of this analysis is to identify those areas which are most and least vulnerable to sinkhole formation, the existence or formation of small fractures which can serve as conduits to the ground water, or subterranean features such as old collapsed sinkholes or solutions. Vulnerable locations should remain in open space, perhaps as interconnected green space, or should be used for lower intensity land uses. Most of the area's development and especially the more intensive land uses should be sited in the less vulnerable areas.

2. TYPE OF DEVELOPMENT

Essentially, there are two primary types of development: (a) sprawl, and (b) compact. Each type has its own advantages and disadvantages. With respect to the goals of this project a combination of the approaches probably is warranted. The greatest amount and intensity of development should be designed as "planned unit developments" which clusters development. This targets development to areas with soils and geology appropriate for development and allows for minimization of imperviousness by decreasing the need for roads. Sprawl type development can be used for large lot developments which, depending on the area's soils and geology, may also be the best way to minimize ground water pollution potential. I don't have the time to go into any detail, but if land uses such as golf courses are anticipated or desired, special design requirements are needed.

3. SPECIFIC NONSTRUCTURAL CONTROLS

A. Minimize Imperviousness, Especially Directly Connected Impervious Areas

- Assure that commercial parking requirements are appropriate for expected traffic flow
- Review requirements for road widths and see if they can be reduced without jeopardizing public health or safety
- Promote the use of alternative parking lots materials such as Geoweb with sod or gravel, turf blocks, etc. These are especially appropriate on parking spaces that are rarely used and which are farthest from the store.
- Encourage the use of pervious pavement. I make this recommendation with caution. Using pervious pavement needs to be based upon local site conditions, experience, testing, and expertise of the community's engineers and contractors. In Florida, we have had very good experience with pervious concrete but not porous asphalt.
- Require the use of swales instead of curbs and storm sewers, at least in residential areas. Swale blocks or raised driveway culverts should be used to retain the water within the swale and let it infiltrate. Of course, the swale must be fully vegetated, preferably with a dense grass and should be established by sodding. This is especially true to minimize the movement of stormwater pollutants through the soil and into the ground water. Even in commercial parking lots, swales should be an essential part of the BMP treatment train. For example, parking lot islands can be recessed, sodded, landscaped, and curb cuts used to allow runoff to flow into these mini-retention/swale areas. These can be interconnected into a conveyance system leading to an infiltration or other stormwater BMP. Alternatively, but less preferred, a storm sewer inlet can be placed in the bottom of the mini-retention area with the inlet raised above the bottom of the area to promote settling and infiltration.

- Require roof runoff to be directed into pervious areas not onto parking lots or driveways. On commercial sites, the roof runoff can be directed into landscape islands or other grassed/vegetated areas. At home it can be directed onto lawns or into flower beds.

B. Protection of Critical Areas

- Buffer zones should be required around all sinkholes, springs, and fractures. The width depends on site-specific factors such as land use type and intensity, soils, slopes, etc. In addition to buffer zones, minimum set backs should be considered. For example, stormwater systems and on-site wastewater systems should be set back 100-300 feet from critical areas.
- Minimize the amount of land which is cleared. This can be accomplished through local codes by requiring a minimum area of a site to be maintained in natural condition (i.e., Tallahassee requires 20%) or by requiring the careful scheduling and staging of construction, preferably using both methods.

C. Pollution Prevention

It is very important for the citizens, elected officials, and businesses within the watershed and the community to understand the tremendous potential for nonpoint sources to contaminate the ground water and spring system. It is vital to understand the concept of **"Pointless Personal Pollution"**. The greatest threat to the quality of the water resources is from the every day activities of the citizens and businesses which reside, work, play, or travel through the watershed. It is the insidious, cumulative effects of these many small actions which pose the greatest threat to the ground water system. That's why a public education program is so important - to educate citizens and businesses about how their everyday activities can potentially introduce pollutants into the waste stream and around the watershed and what they can do to alter behavior and otherwise lessen the potential for pollution. Potential BMPs include:

- Street and parking lot sweeping using vacuum sweepers
- Detecting and eliminating illicit connections to the stormwater system
- Proper handling, use, and disposal of fertilizers and pesticides. Even better, use "natural landscaping" and promote by demonstrations of the "Missouri Yard".
- Proper handling, use, and disposal of household chemicals. Establishment of household hazardous materials recycling and waste disposal centers. Community demonstration project of recycling old paints, remixing to create "mix color paint" that is used for public or charitable purposes.
- Proper disposal of pet wastes - a major source of coliforms and other pathogens.
- Opportunities at businesses or industries:
  - Require pollution prevention plans and employee training on proper use and disposal of materials that are potentially damaging to ground water.
  - Review of materials, especially solvents and other liquids, used in processing and replacement with less hazardous or toxic materials.
  - Proper siting, storage, and, where necessary, containment of materials. For example, loading docks, storage areas, and equipment maintenance and storage areas are good areas for roofing to minimize exposure to rainfall and runoff. Another good example is the storage of fertilizers and pesticides at lawn and garden centers at most stores.

These materials are stored in plastic bags (which tear), on pallets, outdoors where they are exposed to rainfall and where their contents can easily enter the runoff coming from the store, usually by entering a very nearby storm sewer inlet.

D. Winter Road Management

Snow removal and storage along with salt application and storage can corrode bridges, roads, and vehicles and contribute to several adverse environmental conditions, including damage to roadside vegetation, increased chloride levels in ground and surface waters, general degradation of water resources. These effects can be reduced or prevented by:

- Carefully siting snow storage areas so that runoff or seepage from the snow pile doesn't harm waters and is properly treated before discharge.
- Minimizing or eliminating the use of salt (sodium chloride). Alternatives include sand, calcium magnesium acetate, calcium chloride, etc.
- Storing salt properly which means away from critical or sensitive areas, on impermeable surfaces, and under a roof.

III. INSTITUTIONAL AND PROGRAMMATIC CONSIDERATIONS

Even with the use of structural and non-structural BMPs, the long term success in protecting the ground water and spring resources will depend largely on the institutional framework and the availability of dedicated sources of revenue to fund implementation, monitoring, maintenance, and operation. For more detailed information see Chapters 10, 11, 13, 15, and 16 of Fundamentals of Urban Runoff and the document entitled "Model Local Government Stormwater Management Program". Key components include:

- Watershed approach - perhaps the establishment of a "watershed management district" as the primary legal entity.
- Land use planning and implementation with reliance upon nonstructural approaches
- Land acquisition programs to purchase sensitive areas and to purchase conservation easements or development rights
- Stormwater management which includes erosion prevention and sediment control during construction, and stormwater quantity (peak discharge rate and volume) and quality management for new development and redevelopment. Education programs for developer, designers, engineers, and inspectors are essential. To assure long term operation and maintenance of stormwater systems, operating permits (with annual inspections and renewals) can be required. "Adopt-a-Pond (BMP)" programs can also be established to promote proper maintenance and operation of stormwater systems serving residential developments where a property owners association is the legal maintenance entity. Better yet, keep all systems in public ownership.
- Public education programs including "Eco-Neighborhoods", "Adopt a Sinkhole", "Missouri Yards and Neighborhoods"; storm sewer stenciling programs; booklets, videos, etc.
- Dedicated funding sources such as the establishment of a stormwater utility, or special fees on fertilizers, pesticides, gasoline, etc.
- On-site wastewater management program which conducts regular inspections of on-site systems and assures that necessary maintenance is performed.

IV. STRUCTURAL BMPs

While I did not have much time to spend reviewing the Preliminary Draft of the Structural BMP Study, I want to offer the following comments:

1. I applaud you warning in the transmittal memorandum to Loring Bullard about the limitations of BMP treatment efficiency statements and concur with it wholeheartedly.

2. I am disappointed that the transmittal letter did not stress the importance of the BMP Treatment Train, using a series of BMPs in an integrated system. This is crucial for stormwater systems in a karst area.

3. I am disappointed that stormwater filters are described as "Austin First-Flush Filtration Basins" when the concept originally was developed and required in the State of Florida! I will also note that there are many types of stormwater sand filters including side bank, unconfined, confined, vertical recovery, etc. However, all filters suffer a common trait - it is not a question of if they will clog, but when... and then how to you maintain it to restore it's original operation.

4. I am perplexed why the most useful and valuable BMP in our structural tool box was omitted - namely, retention or infiltration basins. First, you should rename "Retention Ponds" as either "Wet Detention Ponds" or "Extended Detention Ponds" for that is what is described, at least in the standard stormwater nomenclature. Second, given that the goals of this project our to protect ground water/spring flow and quality, and that accomplishing this requires post-development runoff volume (not just peak discharge rate) to equal pre-development volumes, then the most appropriate set of tools we have are the "RETENTION OR INFILTRATION" tools (See enclosed paper). These include a wide variety of BMPs including swales, infiltration trenches, and porous (pervious) pavement which were including in this document, but also infiltration basins, exfiltration trenches, dry wells. By infiltration basins I mean areas integrated within a site's green space or landscaping into which the "first flush" (whatever that means in inches) is directed and allowed to infiltrate into the soil and through it into the ground water. To minimize the vertical transport of stormwater pollutants, especially dissolved ones, a thick vegetative cover is required, typically lawn grass which is established by sodding. The thin layer of top soil attached to the sod (or a thin topsoiling of the soil as preparation for sodding) provides organic matter which increases the cation exchange capacity of the sandy soil thereby decreasing pollutant transport. The vegetation also helps reduce suspended solids by stabilizing soils (pollution prevention) and it also helps to reduce stormwater pollutants by filtration (pollution treatment). Additionally, the vegetation roots help to maintain a more pervious surface area.

4. I have enclosed our stormwater treatment requirements for developments within karst areas along with information on their operation and maintenance. Additionally, I have included our design guidelines for retention (infiltration) areas. In submitting a stormwater permit application, developers in these areas must submit additional information about the site's hydrogeology. This may include borings at various locations, especially wherever stormwater management system components are located; soil type and thickness to limerock; location of all

sinkholes or fractures; location of all depressions which may represent relict sinkholes; etc.To summarize very briefly:

- Treatment should be via the BMP treatment train involving all practical infiltration practices along with appropriate other techniques as required (ie. oil and grease traps/separators for certain land uses).
- Treatment should be off-line. Before the "treatment volume" can be specified two essential steps must be taken. First a "performance goal" or minimum treatment goal should be established. The state stormwater programs in Florida, Maryland, and Delaware all have set a minimum treatment level equal to removal of 80% of the average annual loading of TSS. This also is the goal set in the Section 6217 Coastal NPS Control Program BMP guidelines. However, be forewarned that this level of treatment probably is not high enough accomplish this project's goals. Second, once the performance standard is determined, then design criteria must be established for the various BMPs that are going to be allowed. For off-line infiltration areas, the treatment effectiveness is equal to the percent of the annual runoff volume which is diverted, retained and infiltrated. Therefore, to establish design criteria, whether for retention or detention systems, long term precipitation records for the area should be statistically analyzed to develop Precipitation-Interevent-Frequency data which can be used to develop diversion or treatment volume curves.
- Treatment should be via shallow, vegetated infiltration areas distributed around a site.

APPENDIX 7
ANALYSIS OF STRUCTURAL BEST MANAGEMENT PRACTICES

EXTENDED DRY DETENTION BASINS

DESCRIPTION:

Extended dry detention (ED) basins are designed to completely empty at some time after stormwater runoff ends. These are adaptations of the detention basins used for flood control. The primary difference is in outlet design; the extended basin uses a much smaller outlet that extends the retention time for more frequent events so that pollutant removal is facilitated. A 40-hour drain time for a capacity volume is recommended to remove a significant portion of fine particulates and provide streambank erosion control (UDFCD, 1992; Schueler, 1987). The term "dry" implies that there is no significant permanent water storage. (UDFCD, 1992) (Illust.)

Many designers encourage a two stage design in which the upper stage is dry except for infrequent large storm events and the lower stage is regularly inundated, with a volume equal to the runoff from the mean storm.

GENERAL APPLICABILITY / EXPERIENCE WITH TECHNIQUE ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Significant areal requirement limits use by open area availability; not typically a site-based BMP.
   - Retrofitting to established developments may be very difficult due to areal requirements.

b. Typical Applications
   - Extended dry detention basins can reduce peak stormwater runoff rates while trapping sediment loads, particularly when used downbasin from construction sites. Sediment from such high loads will need to be removed, however. They can be used to improve runoff water quality from roads, parking lots, residential, commercial and industrial areas. Typically, they are used in conjunction with other onsite BMPs.

c. Design Considerations
   - Land requirement is typically 0.5 to 2.0 percent of drained area (UDFCD,1992)
   - The volume of runoff detained should be based on local hydrology and available area; detention for 90% of all storms is often used (Shaver, 1994).
   - Addition of a small wetland marsh or ponding area in the basin's bottom may enhance soluble pollutant removal, however storms may flush out trapped sediments and minimize this benefit.

d. Other Experiences with BMP
   - Extended dry detention basins have performed well in sediment and associated pollutant removal efficiencies. They also prevent streambank erosion. Problems noted include clogging of the outlet and detention times significantly lower than design (Galli, 1992). The use of more

sophisticated computations for determining volume (rather than design runoff/design detention time) may solve the latter problem.

DEMONSTRATED ABILITY TO PROTECT GROUNDWATER QUALITY:

- Removal efficiencies; (EPA,1986; Grizzard et al., 1986; Whipple and Hunter, 1981)

Suspended Solids	50-70%
Total Phosphorus	10-20%
Total Nitrogen	10-20%
Zinc	30-60%
Bacteria	50-90%
Lead	75-90%

Galli, F.J., 1992:

Lead	62%
Zinc	57%

- For soluble pollutants (e.g. phosphorous, nitrogen, zinc), the removal performance appears to be more consistent than for retention ponds or wetlands, although the latter have higher maximum removal rates. Removal rates for less soluble constituents are somewhat less than those for retention ponds or wetlands (Urbonas and Stahre, 1993).

- Due to the wide range of variability for pollutant removal, a conservative estimate near the low end of the ranges reported should be assumed.

- Infiltration is not a major mechanism in dry basins; as a result, groundwater quality is not typically threatened.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Since the above numbers refer to stormwater released from the basin, protection of other resources can vary considerably. Proper design and placement are generally considered the keys to effective protection of downstream resources.

ADVANTAGES:

- Moderate to high removal of particulates and suspended heavy metals
- Infiltration and resultant recharge to groundwater is minimal compared to infiltration type BMPs, therefore, the risk of direct introduction of contaminants to groundwater is also minimal. Trapping and storage of runoff protect sinkholes.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Pests, accidental drowning during storm events

b. Environmental Risk and Implications
   - Possible stream warming and habitat destruction
   - High ground water levels may inundate the basin and outlet (use retention pond); ground water mounding may occur with slow-draining or silt-clogged soils.
   - Thermal modification to downstream waters should be minimal (Schueler, 1987)

c. Other
   - Construction costs may be high if bedrock is to be excavated.
   - Will likely have negative aesthetics unless a lower-stage basin is used.
   - Can become a trash dump if not maintained.
   - Breeding grounds for mosquitos and other insects.
   - Aesthetics; debris and sediment accumulation, as well as overall design.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Moderate capital cost per acre served (UDFCD, 1992). Empirical data from a Washington D.C. study (Weigand et al. 1986) gives an empirical formula of;

     $\$ = 10.71 * (\text{Storage Volume})^{0.694}$;

     where $ = 1985 dollars and Storage Volume is in cubic feet, and greater than 100,000 cu. ft.

b. O&M Costs
   - Annual O&M costs of 3-5% of construction cost, with non-routine sediment removal costs of 20 to 40% of first cost at intervals of ten years or more. This non-routine maintenance can be greatly reduced by the use of a forebay.
   - Within the size of drainage area treated, this is typically the least expensive BMP (Schueler et al. 1992).

c. Longevity
   - 20+ years, but frequent clogging and short detention times are common.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

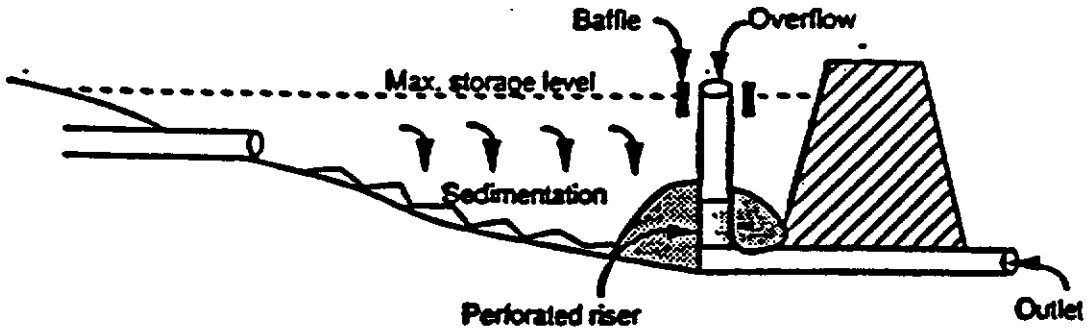
a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Debris and sediment accumulation can be unsightly; use of low slopes and lawn management can help public acceptance.
   - The area required for this BMP may be seen by a developer as a "taking". Solid, defendable engineering information must be provided to justify requirement of this BMP to a developer.

b. Equitability to Impacted Persons
c. Amenity or Multi-Use Value
   - Extended ponds have been used for: recreational fields, tennis courts, parking lots, roof tops, nature areas, etc.
d. Fit with other Operations and Programs
e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - Exfiltration will tend to decrease over time as the bottom becomes clogged with sediment; this may be a positive factor in preventing ground water contamination.
b. Routine and Non-routine Maintenance
   - Cleanup of debris and trash, pest and overgrowth control, erosion repairs, inspect for structural damage to outlets, clogging of outlet.
   - A five to ten year sediment cleanout cycle is recommended (Schueler, 1987)
c. Sustainability of Maintenance or Program Management
   - Regular maintenance and sediment cleanout are not technically difficult; long-term management should not be problematic.

DRY DETENTION PONDS



- EFFICIENCY: POOR FOR DETENTION TIMES UNDER 12 HRS.

  GOOD FOR DETENTION TIMES GREATER THAN 24 HOURS

- FUNCTION: SETTLE POLLUTANTS OUT; SOLUBLE POLLUTANTS PASS THROUGH

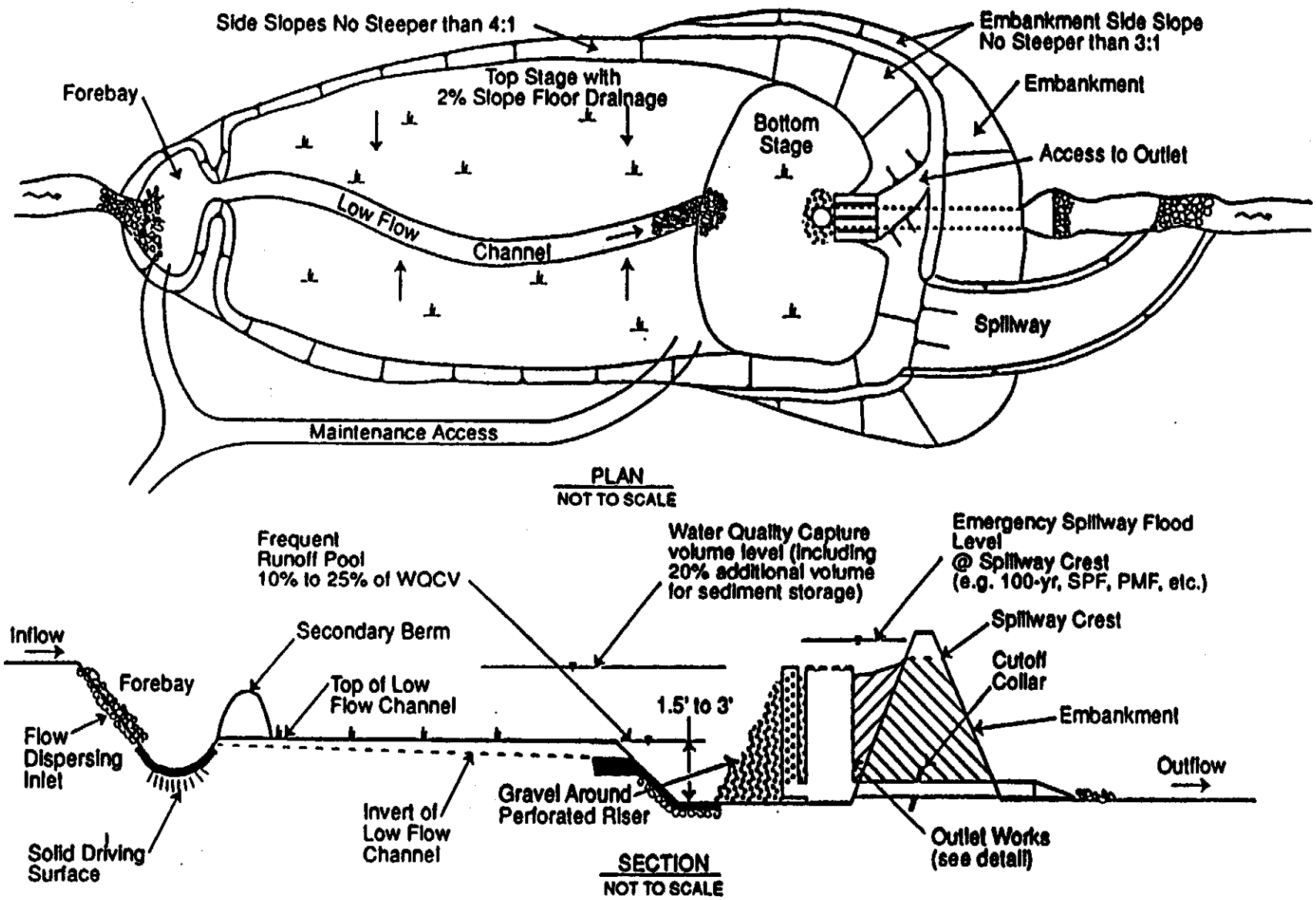
- MAINTENANCE IS MODERATE IF PROPERLY DESIGNED

- IMPROPER DESIGN CAN MAKE FACILITIES AN EYESORE AND A MOSQUITO-BREEDING MUDHOLE

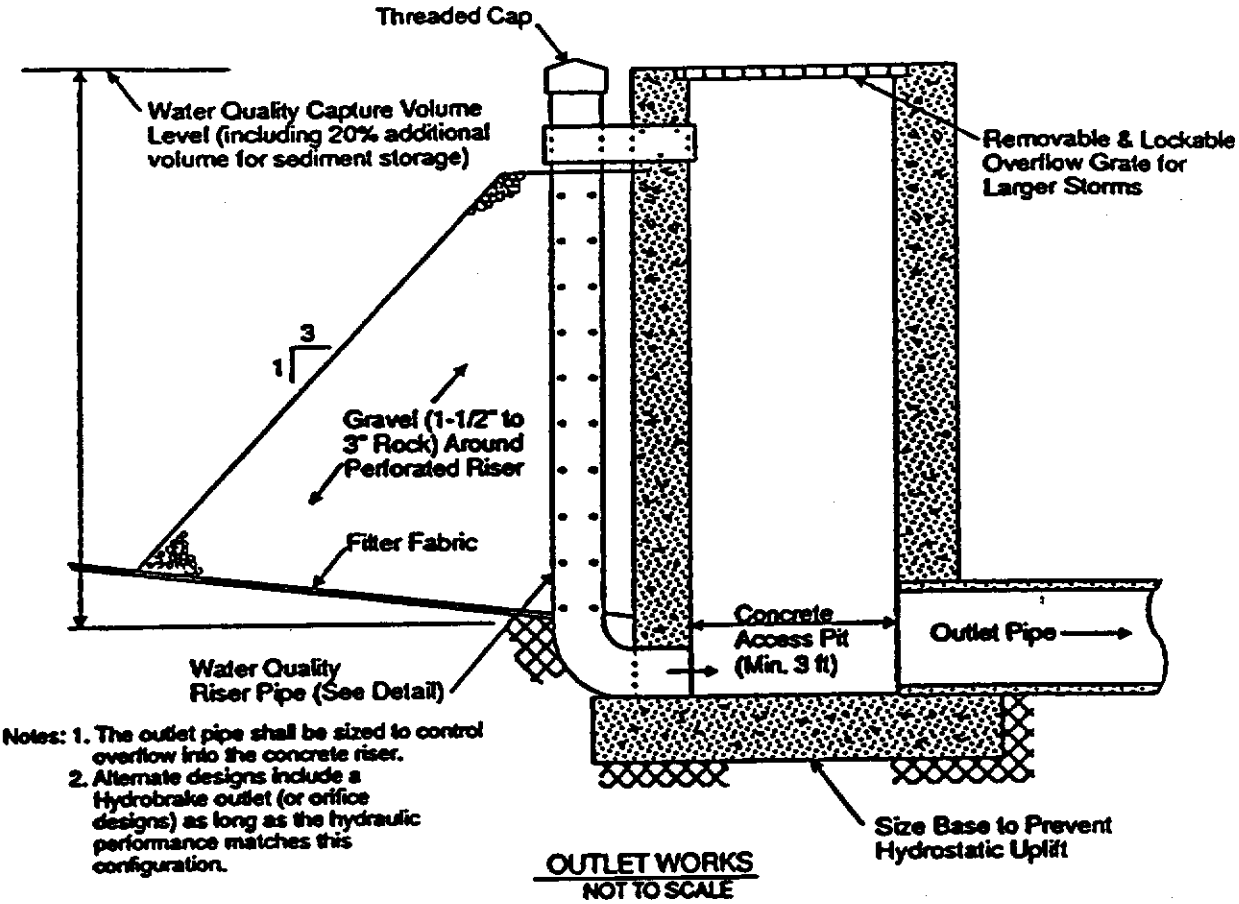
- NEWER DESIGNS ARE INCORPORATING A SHALLOW MARSH AROUND OUTLET. RESULT: BETTER REMOVAL EFFICIENCY AND NO MOSQUITO NUISANCE

- REGIONAL DETENTION FACILITIES SERVING 100 - 200 ACRES CAN BE AESTHETICALLY DEVELOPED
  RESULT: LOWER MAINTENANCE COSTS

ASCE, 1990-91



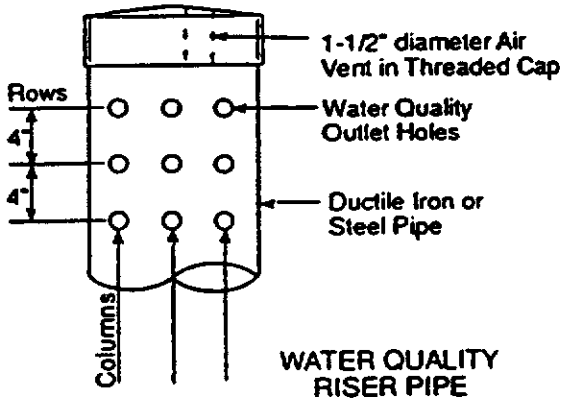
PLAN AND SECTION OF A DRY EXTENDED DETENTION BASIN



Notes: 1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

OUTLET WORKS
NOT TO SCALE

Notes: 1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" dia.



WATER QUALITY RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter (in.)	Area of Hole (in.^{2})
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

WATER QUALITY OUTLET FOR A DRY EXTENDED DETENTION BASIN

9-1-1992
UDFCD

WET DETENTION PONDS

DESCRIPTION:

A wet detention pond is designed to not drain dry as in the dry basin design; a permanent pool of water is replaced in part by stormwater during an event. The design is such that capture volume is released in about 12 hours, but the hydraulic residence time (HRT) for the permanent pool volume is two weeks or longer. Reduction of volume in the permanent pool is through evapotranspiration and infiltration only. For arid or semi-arid climates, a dry weather base flow is required to maintain the permanent pool. (UDFCD, 1992) (Illus.)

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Typically not a site-based BMP, but wet detention ponds are effective in settings where adequate open area exists. Due to the area required, it is difficult to retrofit to a completely urbanized watershed.

b. Typical Applications
   - Since evaporation can quickly dry up base flows, wet detention ponds work best in areas with low ET rates and/or non-arid climates.
   - Wet detention ponds can reduce peak stormwater runoff rates while trapping sediment loads, as well as provide some biological uptake of nutrients. They can be used downbasin from construction sites, but sediment removal is difficult. They can be used to improve runoff water quality from roads, parking lots, residential, commercial and industrial areas. Typically, they are used in conjunction with other onsite BMPs.

c. Design Considerations
   - Effective pollutant removal is directly dependent on sufficient runoff detention time.
   - Use of side slopes of 3 or 4:1 or greater facilitates mowing.
   - Land requirement is typically 0.5 to 2.0 percent of drained area (UDFCD,1992).
   - Incorporating a wetland design or wetland vegetation into the pond can increase contaminant removal rates. This may also encourage wildlife habitation which can help in mosquito and pest control.
   - The inclusion of a forebay is recommended to reduce sediment loads and deposition in the main pond.
   - If fast draining soils are present, a liner may be needed to sustain baseflow; conversely, if bedrock is present and needs to be excavated, construction costs may become very high.

d. Other Experiences with BMP
   - Wet detention ponds are generally more effective at removing nutrient loadings than dry basins; their use is encouraged where nutrient loads are a major contributor to water quality problems (Hartigan, 1989)

- According to the NURP study, basins which exhibit high removal efficiencies are sized such that the mean storm displaces only about 10% of the available volume, and overflow rates (QR/A = mean runoff rate/basin surface area) are a small fraction of the median particle settling velocity (EPA, 1993). The study concluded that wet detention ponds are capable of providing very effective removal of pollutants in urban runoff.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Removal efficiencies for effluent; (EPA,1983)

Suspended Solids	91%
Total Phosphorus	0-80%
Total Nitrogen	0-80%
Zinc	0-70%
Lead	9-95%
BOD	0-69%

Yousef, Y.A., et al. 1986:

A well-oxygenated pond with minimum organic debris appears to provide the environment for improved removal efficiencies of nutrients and selected heavy metals. Also, it was concluded that slower infiltration rates and increased mean residence time favor retention of metals within the sediments. There was no evidence of metals migration within the sediments or that a contamination hazard exists to nearby surface or ground water.

Contaminant	Removal in pond
Dissolved Lead	54.5%
Particulate Lead	95.1%
Dissolved Zinc	88.3%
Particulate Zinc	96.2%
Dissolved Copper	49.7%
Particulate Copper	77.0%
Dissolved Phosphorous	90.1%
Particulate Phosphorous	11.4%
Organic Nitrogen	11.0%
Ammonia	81.6%
Nitrates + Nitrites	86.5%

Hartigan (1989) reports expected removal rates of 40 - 60% for phosphorous and 30 - 40% for nitrogen. Additionally, a minimum Basin area / tributary area ratio of 1% is recommended for high removal rates; 3% for poorly draining soils.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Since the above numbers refer to stormwater released from the basin, protection of other resources can vary as these vary. Proper design and placement are generally considered the keys to effective protection of downstream resources.

ADVANTAGES:

- Cost-effective for larger tributary watersheds
- Moderate to high removal rates of many urban pollutants
- Creates wildlife habitat
- Provides recreation, aesthetics, open space areas
- More efficient sedimentation than dry basin, since outlet is above the basin bottom, leaving a 'dead zone' to trap sediment
- Infiltration and resultant recharge to ground water is minimal compared to infiltration type BMPs, therefore the risk of direct introduction of contaminants to ground water. Trapping and storage of runoff protect sinkholes.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Accidental drownings

b. Environmental Risk and Implications
   - Attract waterfowl, which may increase downstream nutrient loading and bacteria.
   - Inadequate base flow can cause very high concentrations of salts, nutrients, and algae through evaporation, resulting in significant downstream loadings from smaller events.
   - Possible low DO effluent, stream warmings, trophic shifts, habitat destruction, loss of upstream channels.
   - Large events or low dissolved oxygen content can cause mixing or resuspension of deposited sediments, increasing turbidity and metals concentrations.

c. Other
   - Higher cost than conventional stormwater detention.
   - Difficult sediment removal.
   - Floating litter, scum and algal blooms, odors, insects.
   - Bottom of pool may need to be lined to maintain permanent pool in well-draining conditions.
   - Wet detention ponds have greater storage capacity requirements than dry ED basins, resulting in higher capital costs.
   - Large basins may require a dam safety permit.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Moderate capital cost per acre served (UDFCD, 1992)

- Empirical data from a Washington D.C. study (Weigand et al. 1986) gives an empirical formula of;

  $\$ = 33.99 * (\text{Storage Volume})^{0.644}$;

  where $ = 1985 dollars and Storage Volume is in cubic feet, and greater than 100,000 cu. ft.
- Higher capital costs than dry ED basins by 25 to 40% (Debo, 1994)

b. O&M Costs
- Annual routine O&M costs of approximately 3 to 5% of first cost; mowing is the largest component to maintenance, and this can be reduced by maintaining the pond buffer as a meadow instead of a lawn.
- Non-routine sediment removal at 5 to 20 year intervals can exceed $100,000 for very large basins with a cost of $6.25 to $22.40 per cubic yard in 1986 dollars (Weigand et al. 1986). Sediment removal costs can be reduced by as much as 50% if an on-site sediment disposal area is reserved. Other site considerations can further reduce costs.

c. Longevity
- 20+ years

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
- Surveys show that wet detention ponds typically enjoy good public acceptance, particularly when compared to dry detention basins.
- The area required for this BMP may be seen by a developer as a "taking". Solid, defendable engineering information must be provided to justify requirement of this BMP to a developer.

b. Equitability to Impacted Persons

c. Amenity or Multi-Use Value
- Provides recreation, aesthetics, possible open space areas
- Provides aquatic and wildlife habitat

d. Fit with other Operations and Programs

e. Relationship to Federal, State or Local Requirements
- Many natural sites are also natural wetlands protected under federal and possibly state and local laws

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

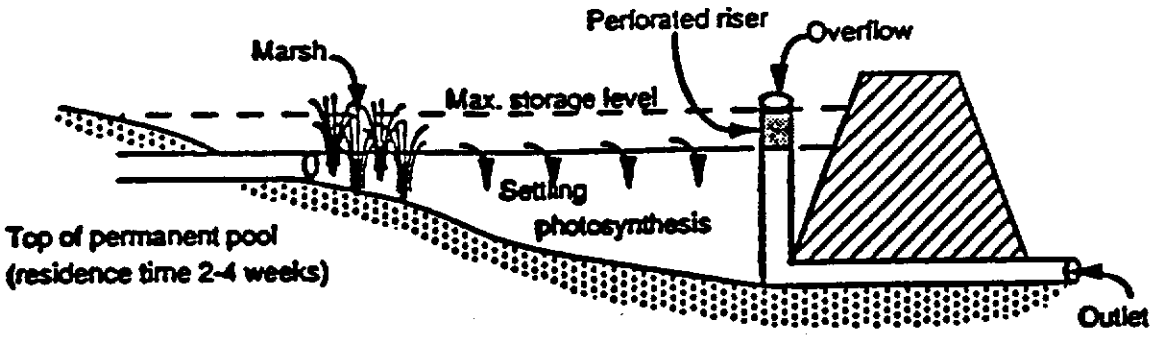
a. Reliability and Consistency over Time
- May be more efficient over time due to increased vegetation providing enhanced nutrient and metals removal rates

b. Routine and Non-routine Maintenance
- Sediment removal at 10 to 20 year intervals (Weigand et al. 1986)
- Routine removal or floating litter and debris.
- Control of scum and algal blooms, odors, insects.
- Nonroutine removal of aquatic plants

c. Sustainability of Maintenance or Program Management

- Funds must be budgeted for routine and non-routine maintenance, particularly considering the high cost of sediment removal. For this reason, public rather than private maintenance is preferred (Schueler, 1987)

WET DETENTION PONDS



- EFFICIENCY: EXCELLENT IF PROPERLY DESIGNED

  CAN BE POOR IF BOTTOM GOES ANOXIC

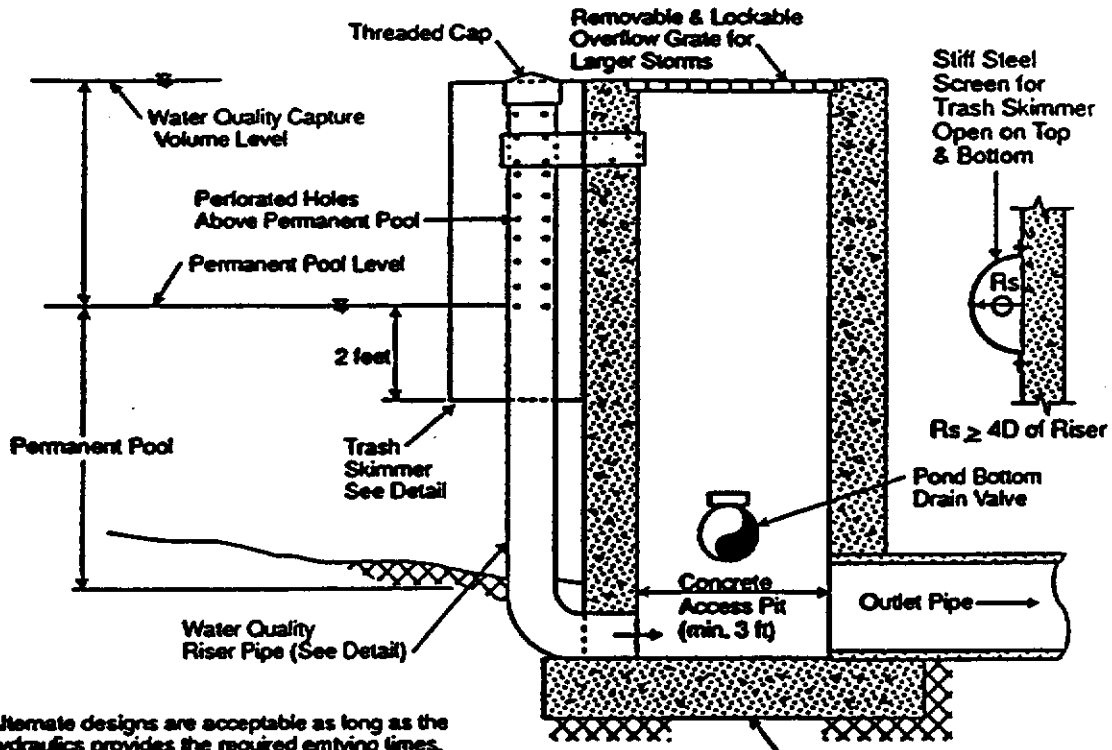
- FUNCTION: REMOVES POLLUTANTS BY SETTLING, AND DISSOLVED POLLUTANTS BIOCHEMICALLY

- MAINTENANCE: RELATIVELY FREE AFTER FIRST YEAR EXCEPT FOR MAJOR CLEANOUT AT ABOUT TEN YEARS

- AESTHETIC DESIGN CAN MAKE POND AN ASSET TO COMMUNITY. ADJACENT PROPERTY ACTUALLY INCREASES IN VALUE

- EXCELLENT AS A REGIONAL FACILITY

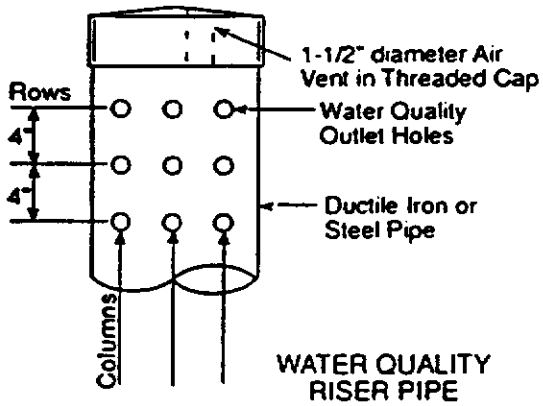
ASCE 1990-91



Notes: 1. Alternate designs are acceptable as long as the hydraulics provides the required emtying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft. below the permanent pool level.

OUTLET WORKS
NOT TO SCALE

Notes: 1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" Dia.



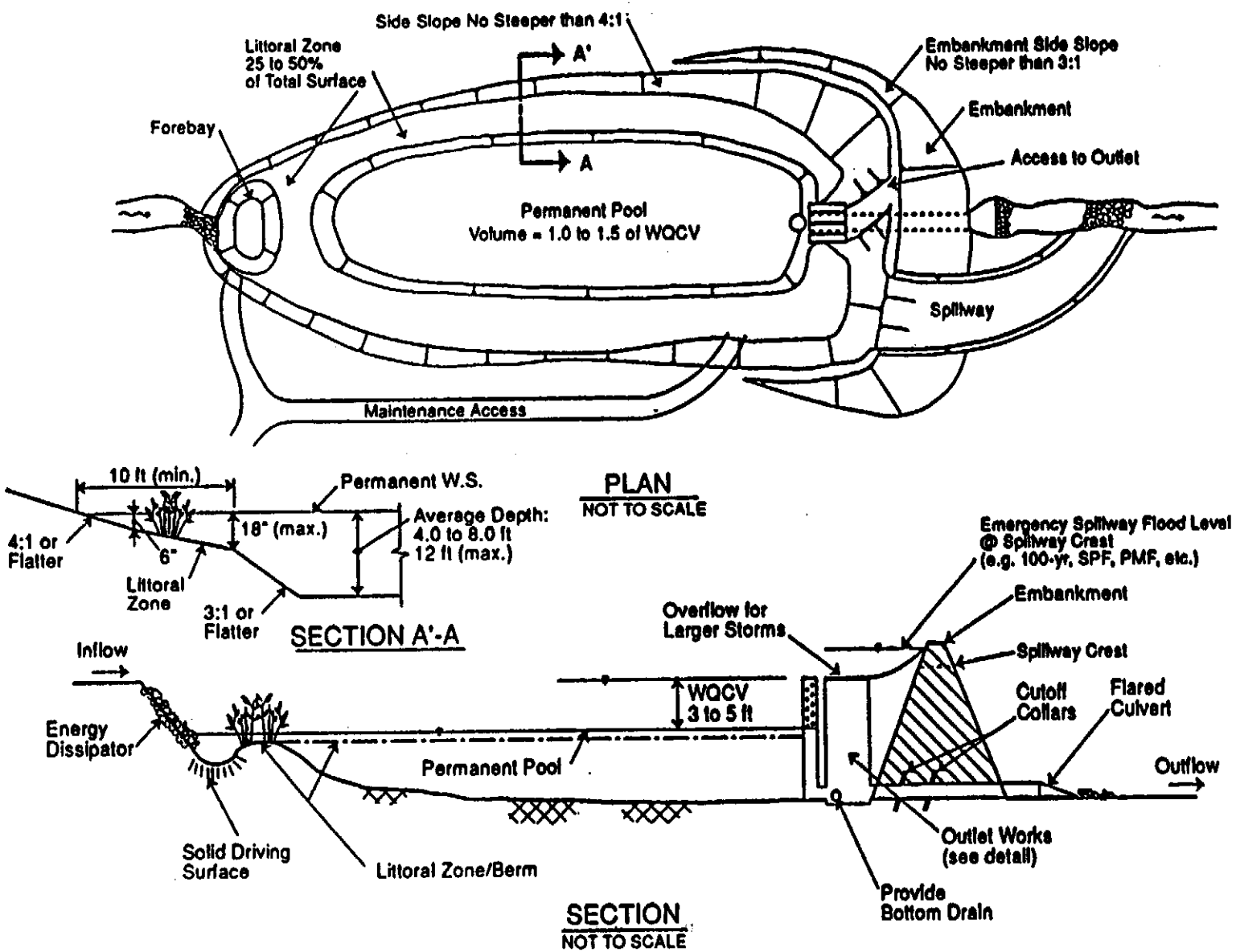
WATER QUALITY RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, inches			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

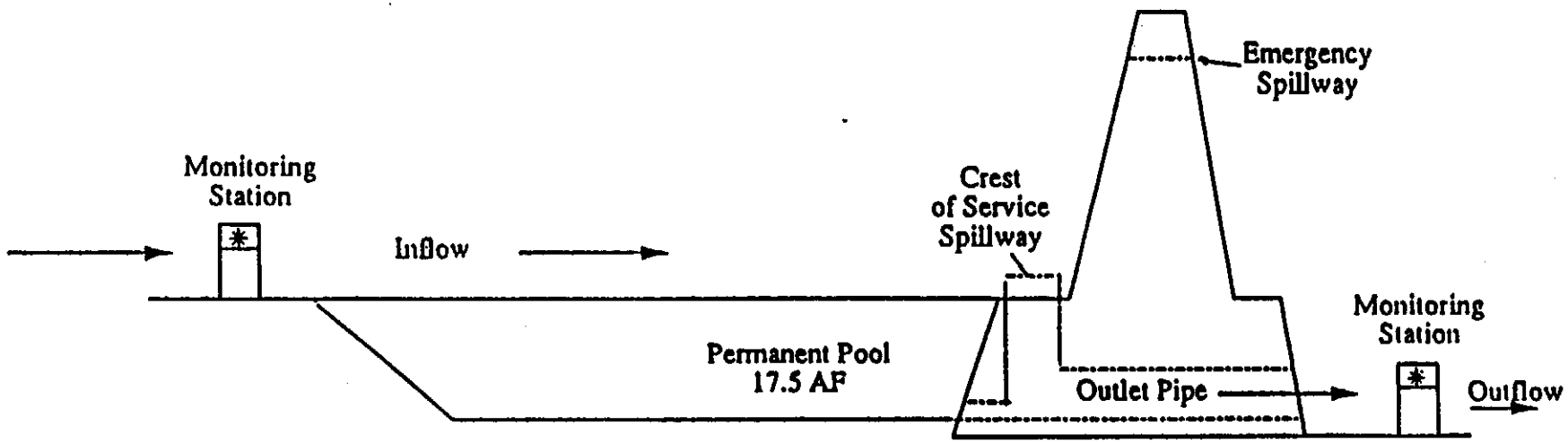
Hole Diameter (in.)	Area (in.^{2})
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

WATER QUALITY OUTLET FOR A WET EXTENDED DETENTION BASIN

9-1-1992
UDFCD



PLAN AND SECTION OF A WET EXTENDED DETENTION BASIN



CONCEPTUAL PLAN OF WOODHOLLOW WET POND

CONSTRUCTED WETLANDS

DESCRIPTION:

These can take the form of very shallow retention ponds or wetland-bottomed channels. A perennial base flow is needed to encourage the growth of wetland species such as rushes, willows, cattails, and reeds. These slow runoff and promote settling and biological uptake. "Pocket" wetlands are typically under a tenth of an acre in size, serving developments of 10 acres or less. These are usually less reliable and efficient than larger wetlands.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Wetland basins can be used as a followup BMP in a watershed, or as an onsite facility if the owner can provide sufficient water. Flood control measures may be instituted above the wetland basin.
   - Retrofitting to established developments may be very difficult due to areal requirements.

b. Typical Applications
   - Arid climates or high ET rates can make maintenance of the required base flow difficult. Also, short growing seasons may inhibit vegetation growth and propagation.
   - Wetland bottom channels can be used in two ways: first, a wetland can be established in a man-made channel and can act as both a conveyance facility and a water quality enhancement facility. Perhaps the more effective option is to locate the channel downstream of a stormwater detention facility that will remove much of the sediment load. The channel then provides better quality water to the receiving water body. The detention facility should have at least a 24 hour drain period for the storm event.

c. Design Considerations
   - A water budget analysis is needed to ensure the adequacy of the base flow. Also, loamy soils are needed to permit rooting of plants. A near-zero longitudinal slope is required.
   - A forebay should be included for sediment removal and vehicle access.
   - The stormwater wetland does not attempt to provide the diverse species and ecological functions of a natural wetland; it is designed to maximize pollution removal.

   - Shaver recommends the use of multiple small wetlands over one large one, giving a greater level of control and effect on a greater number of streams.

d. Other Experiences with BMP

- Wetlands for storm water treatment have been used for 10 to 15 years. Estimates for removal rates vary widely in the literature, probably due to a lack of data that would produce design protocols. Some higher removal rates may be the result of testing in experimental wetlands and from wastewater treatment sites which have much higher concentrations of BOD and nutrients.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Pollutant removal efficiencies appear to vary greatly depending on design and environment.
- Removal efficiencies (USGS, 1986, based on 13 sampled runoff events in Orlando, Florida):

Suspended Solids	40-94%
Total Nitrogen	0-21%
Zinc	(-29)-82%
Lead	27-94%
BOD	18%

Lakatos and McNemer (1987):

Total Phosphorus	(-4)-90%

Wright Water Engineers (1991):

Manganese	36-77%
Suspended Solids	29-92% (71% average on eight projects)

Shaver, 1994:

Component	Number of sites			Net Retention	
	Total	Sink	Source	Range	Median
Sediment	8	8	0	23 to 93	76
Total Nitrogen	28	28	0	14 to 100	77
Total Phosphorus	34	25	9	-171 to 98	44

Performance of wetlands receiving stormwater inputs;

Component	Number of sites			Net Retention	
	Total	Sink	Source	Range	Median
TSS	26	24	2	-300 to 96	76
Total Nitrogen	11	7	4	-20 to 83	24
Total Phosphorus	28	22	6	-120 to 97	46

Total Lead	8	8	0	6 to 94	83

- Some claims of high removal rates of nutrients from stormwater may be based on data from experimental wetlands and from wastewater removal rates, where influent concentrations are much higher.
- Nitrification and Denitrification are dependent on many variables, with detention time perhaps the most significant; Shaver (1994) recommends 14 days.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Shaver and others have specified what variables are key to wetland performance. It is apparent that proper design is key to protecting downstream resources, although much work remains in quantifying design parameters for a given climate, drainage area, etc. Generally, it is agreed that wetlands are potentially very valuable for downstream protection.

ADVANTAGES:

- Aesthetics, wildlife habitat, erosion control, pollutant removal, education value, good public acceptance.
- Peak flow reduction.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Minimal, if the water levels are designed to be held below 3 feet (Shaver, 1994). Also, mature wetlands tend to have dense vegetation that discourages human entry.

b. Environmental Risk and Implications
   - Possible stream warming may be mitigated through the use of floating-leaved plants (Shaver, 1994).
   - Salts and scum may accumulate and be flushed out with a major storm event.
   - Possible breeding ground for pests, mosquitos. However, the Maryland study (Galli, 1992) found no mosquito larvae at any of nine sites surveyed, and there is evidence that this is the norm for constructed wetlands. The presence of mosquitos may be used as a biological indicator that the wetland needs maintenance or modification to prevent standing water.
   - Effectiveness at removing nitrogen and some forms of phosphates is questionable.

c. Other
   - Need for continuous baseflow in arid or semi-arid climate; note that many wetland species are drought resistant.
   - Need for periodic sediment removal to maintain proper distribution of growth zones and water movement.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Moderate to high capital cost per acre served (UDFCD, 1992). This may vary depending on site characteristics and design.

b. O&M Costs
   - Moderate routine O&M costs, high non-routine costs of sediment removal. Shaver (1994), however, recommends a hands-off approach to maintenance, allowing "natural evolution" of the wetland.

c. Longevity
   - Since few wetlands are older than 10 to 15 years, longevity can only be estimated. However, proper design and maintenance should provide a substantial operational lifetime.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Wetlands enjoy strong public awareness and perceived value at this time, so that "selling" this BMP should not be difficult. Some land will be required and this always brings up the "taking" issue, but if wetlands are included in existing green space requirements this should not be a problem.

b. Equitability to Impacted Persons
   - There should be minimal negative impact, particularly with proper maintenance.

c. Amenity or Multi-Use Value
   - Wildlife habitat enhancement, incorporation into green areas, and public acceptance should generally be expected.

d. Fit with other Operations and Programs
   - Wetlands should be easily incorporated into existing plans and wet ponds, green spaces.

e. Relationship to Federal, State or Local Requirements
   - The legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland (UDFCD, 1992); however, if a natural wetland is modified or disturbed in the process of creating a constructed wetland, regulatory problems may occur.

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

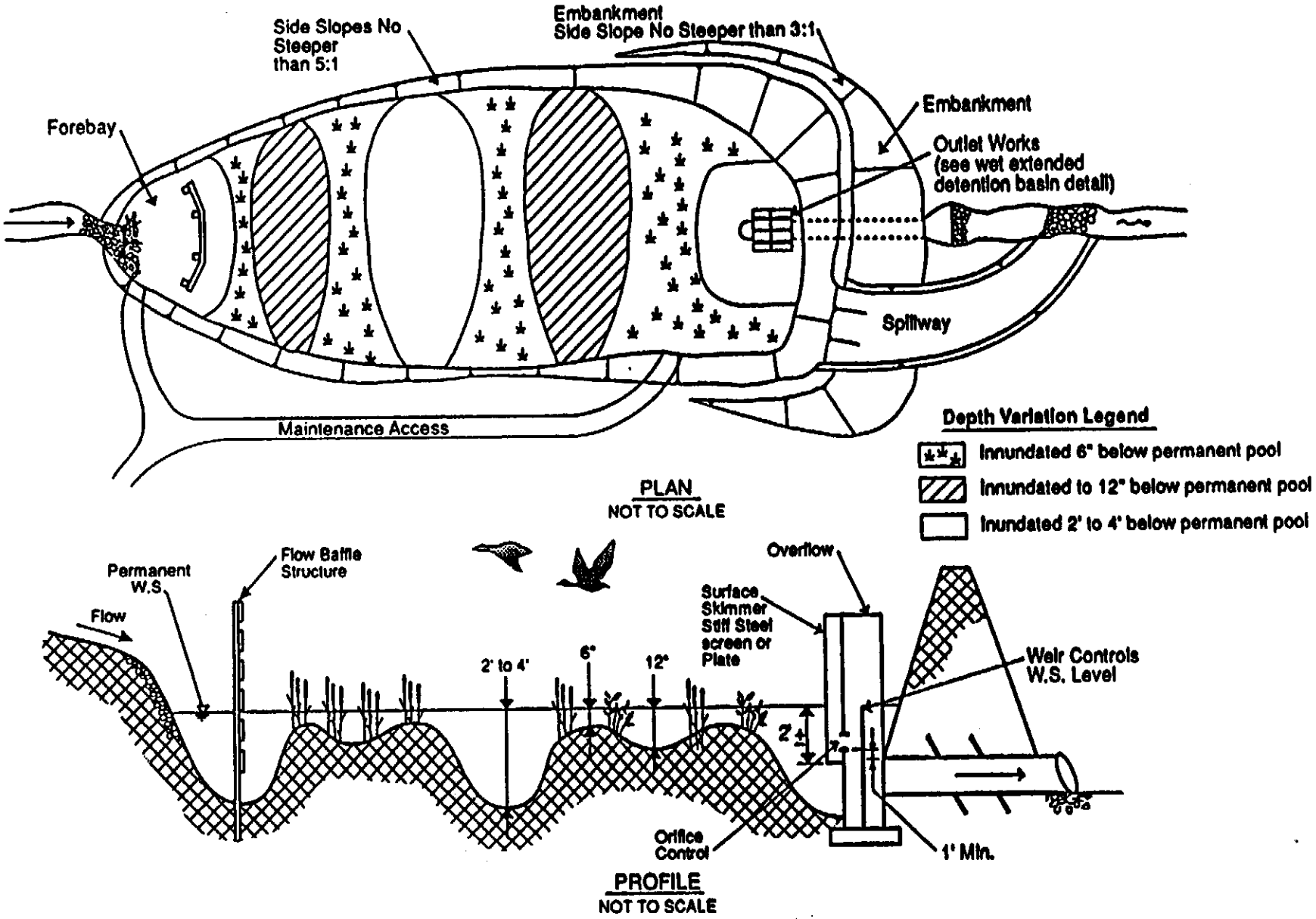
a. Reliability and Consistency over Time
   - Difficult to determine, but with proper design and maintenance the wetland should perform well for an indefinite period of time.

b. Routine and Non-routine Maintenance
   - Proper depth and spatial distribution of growth zones must be maintained

- Remove unwanted vegetation, debris and litter, accumulated sediment and organic muck.

c. Sustainability of Maintenance or Program Management

- Maintenance is generally greatest during the first three years in order to establish vegetation.



PLAN AND PROFILE OF A WETLAND POND

FILTER STRIPS AND FLOW SPREADERS

DESCRIPTION:

- Filter strips are vegetated areas designed to accept sheet flow provided by flow spreaders which accept flow from an upstream development. Vegetation may take the form of grasses, meadows, forests, etc. The primary mechanisms for pollutant removal are filtration, infiltration, and settling.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Can be used as part of almost any landscaping plan for a given site.

b. Typical Applications
   - Filter strips can be used in residential and commercial sites, adjacent to impervious areas. Effectiveness depends on evenly distributed sheet flow, and limited drainage area and runoff volume. For grass filter strips, the environment must support turf-forming grasses; arid and semi-arid climates and cold climates are not usually good candidates. They have limited effectiveness in pollutant removal, and followup structural BMPs will still be required.

c. Design Considerations
   - The proper function of the flow spreader is key to the performance of the filter strip. If flow is allowed to short-circuit or concentrate, the bulk of the filter strip will be ineffective for pollutant removal and flow reduction. This will also result in erosion over time.

d. Other Experiences with BMP
   - A Maryland study (Galli, 1992) of six grass filter systems showed that all filters were showing deterioration and decreased performance 1.3 to 2.6 years after installation. Low grass height was cited as the primary cause of decreased performance; the recommendation was that grass should be left as high as possible between mowings. Also, the invasion of annual grasses and weeds that experience seasonal die-back can greatly reduce filtering performance. It was concluded that all filters would fail within three years due to erosion from high runoff rates unless substantial repairs were made.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- The primary mode of pollutant removal is interception and settling of solids; biological uptake is considered a minimal contributor. Thus, soluble pollutants may show very low removal rates and fairly direct entry into the ground water, although filtration, adsorption, and ion exchange may occur in the underlying soils.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- With proper design and maintenance, these are valuable on-site BMPs for protection of environmental resources. Followup BMPs are often needed, however, in order to maximize erosion control and water quality mitigation.

ADVANTAGES:

- Aesthetics of open, green space.
- Low cost, since developments are typically required to have open space in their plans
- Grasses and shrubs or trees provide wildlife habitat.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Minimal

b. Environmental Risk and Implications
   - The primary flood-control mechanism is infiltration; in areas of high ground water vulnerability, this may not be a good option.

c. Other
   - On unstable slopes, soils or vegetation, rills and gullies may develop that invalidate the usefulness of the strips.
   - Excessive pedestrian or vehicle traffic may damage the vegetation and soils structure. The planting of shrubs and trees can help eliminate both of these disadvantages.
   - Inadequate maintenance of vegetation may result in partially denuded soils with predictable results in erosion, runoff quality and volume.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Capital costs are low and should be considered part of an overall landscaping plan.

b. O&M Costs
   - Routine maintenance costs are usually low. Non-routine maintenance may be required (replacement of turf, soils) if not designed properly or if damaged by traffic.

c. Longevity
   - Limited by improper design, excessive traffic, or poor turf management

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership

- These can be included as part of the landscaping plan for commercial sites.

b. Equitability to Impacted Persons
   - This is not typically a problem.

c. Amenity or Multi-Use Value
   - Aesthetics

d. Fit with other Operations and Programs
   - Since this works well as an on-site BMP, it will probably not work well in retrofitting, but it should be easily implemented into new sites.

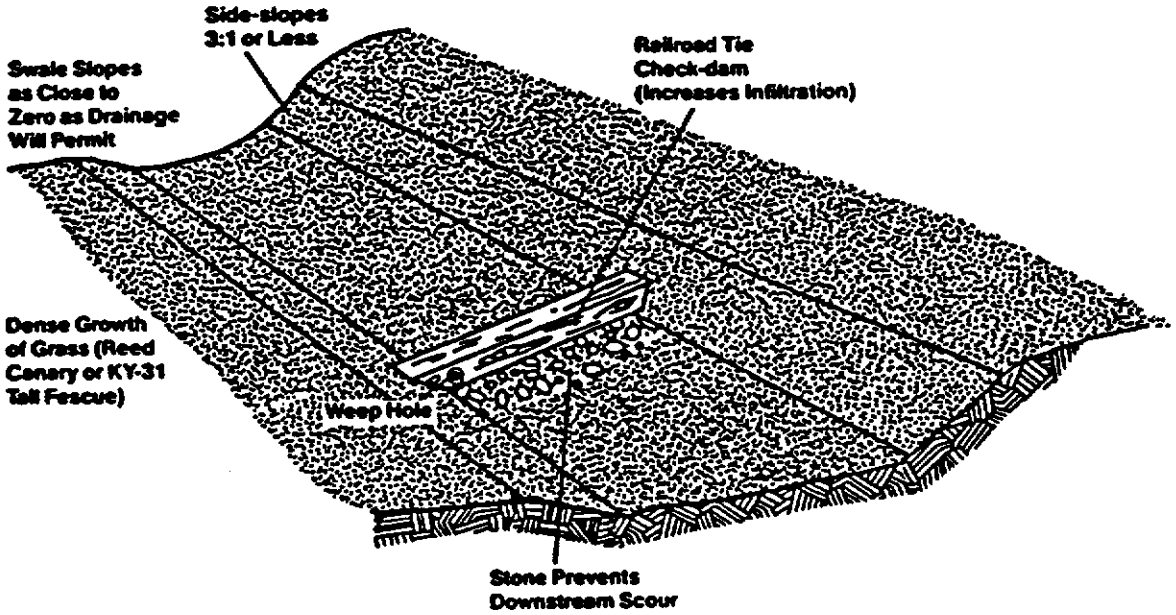
e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

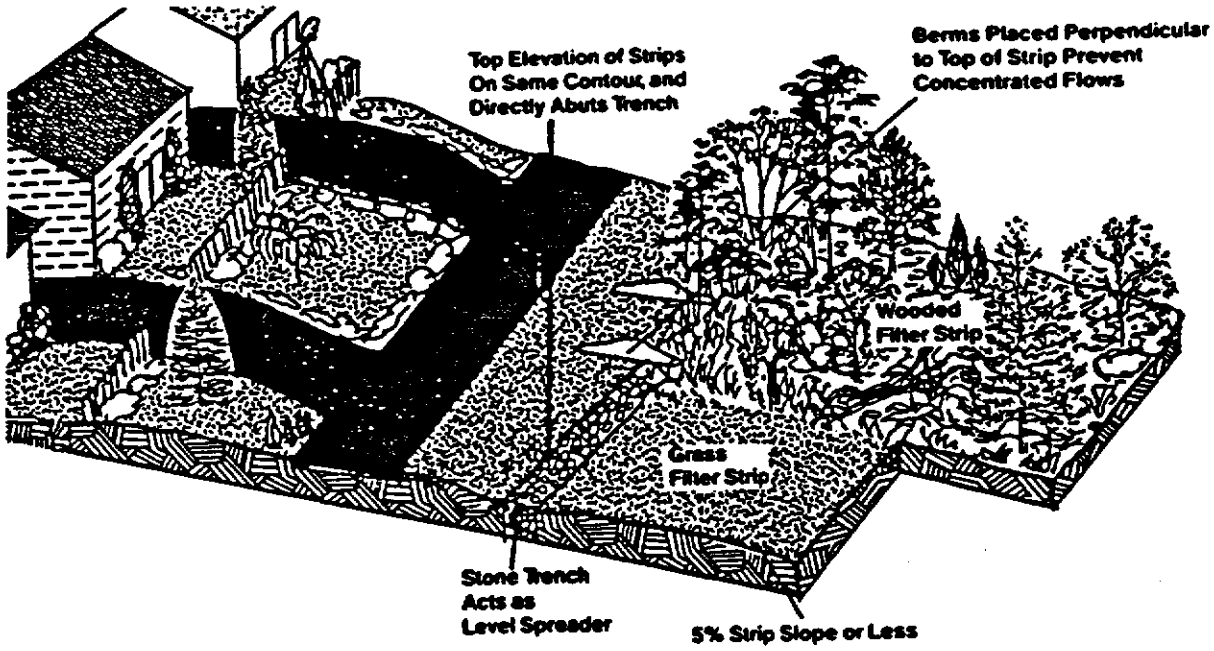
a. Reliability and Consistency over Time
   - The key is proper design and maintenance.

b. Routine and Non-routine Maintenance
   - Routine maintenance consists of standard turf maintenance.
   - Non-routine maintenance consists of turf replacement, soils replacement, and regrading.

c. Sustainability of Maintenance or Program Management
   - Maintenance is not difficult, but must be included in budget planning in order to prevent serious degradation.



Schematic of a Grassed Swale



Schematic of a Filter Strip

GRASSED SWALES

DESCRIPTION:

Grassed swales are densely vegetated drainageways with low-pitched sideslopes that collect and slowly convey runoff. The emphasis is on slow, shallow flow that encourages sedimentation and discourages erosion. They are set lower than the surrounding ground level, allowing runoff to enter the swales over grassy, shallow banks. Check dams may be used in conjunction with the swales to further slow the runoff. If base flow is present, wetland vegetation may also develop.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - May be difficult to retrofit, and care should be taken to avoid high ground water areas or thin soils allowing infiltration to ground water.

b. Typical Applications
   - Grassed swales are restricted to climates that promote growth and propagation of vegetation; arid or very cold climates are not good candidates.
   - Swales are often used to collect overland flow from impervious areas such as parking lots, buildings and roadways, as well as semi-previous areas such as grass filter strips and residential yards. They are often presented as an option to curb-and-gutter systems in order to reduce peak flow rates and reduce pollutant loading downstream. A followup BMP will be required to enhance water quality.

c. Design Considerations
   - Generally well adapted for sites with ground slopes up to 3 or 4 percent, and not over 6 percent. The longitudinal slope of the swale should be less than 1 percent.
   - Low density development is recommended.
   - The NURP study concluded that adequate residence times are key to significant pollutant removal, although parameters were not determined.

d. Other Experiences with BMP
   - The NURP study indicated that grass swales monitored in Washington, D.C. provided no improvement in ground water quality; however a New Hampshire NURP project showed heavy metal reductions of approximately 50% and COD, nitrate, and ammonia reductions around 25%.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Primarily an infiltration practice, so that soluble pollutants may be directed to the ground water.
- Removal efficiencies vary widely; the reasons for this are not well understood.
- Reported removal efficiencies:

Whalen and Callum (1988) suggest TSS removals exceeding 80%

Kercher, W.C., Jr., et al., 1983:

Lead, total	99%

Oakland, P.H., 1983:

Cadmium, total	56%
Cadmium, dissolved	42%
Zinc, dissolved	47%
Copper, dissolved	53%
Lead, dissolved	63%

- The key to effluent pollutant removal may be soils with high infiltration rates and flow velocities of less than 0.5 ft/sec. (Urbonas and Stahre, 1993). This may be inappropriate for areas with high ground water vulnerability.
- Filtration, adsorption, and ion exchange may occur in the underlying soils, reducing the potential for ground water contamination.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Generally good performance in pollutant removal and reduction of peak flows.

ADVANTAGES:

- Aesthetics.
- Effective in reducing runoff in small storm events where other BMPs are less effective.
- Can be used to limit the extent of directly connected impervious areas.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Potential for soggy yards, mosquito breeding, and more right-of-way requirement than for equivalent storm sewers.

b. Environmental Risk and Implications
   - Particularly with small storm events, the primary mechanism is infiltration; in areas of high ground water vulnerability, this may not be a good option.

c. Other
   - Effectiveness is limited by infiltration capacity of soils; conversely, well-draining soils may direct polluted runoff directly to ground water.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Low capital costs

b. O&M Costs
   - Low O&M costs

c. Longevity
   - 20+ years, with proper maintenance

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - These can be included as part of the landscaping plan for commercial sites.

b. Equitability to Impacted Persons
   - Minimal impact

c. Amenity or Multi-Use Value
   - Aesthetics, open space

d. Fit with other Operations and Programs
   - Since this works well as an on-site BMP, it will probably not work well in retrofitting, but it should be easily implemented into new sites, particularly when integrated with current open space requirements.

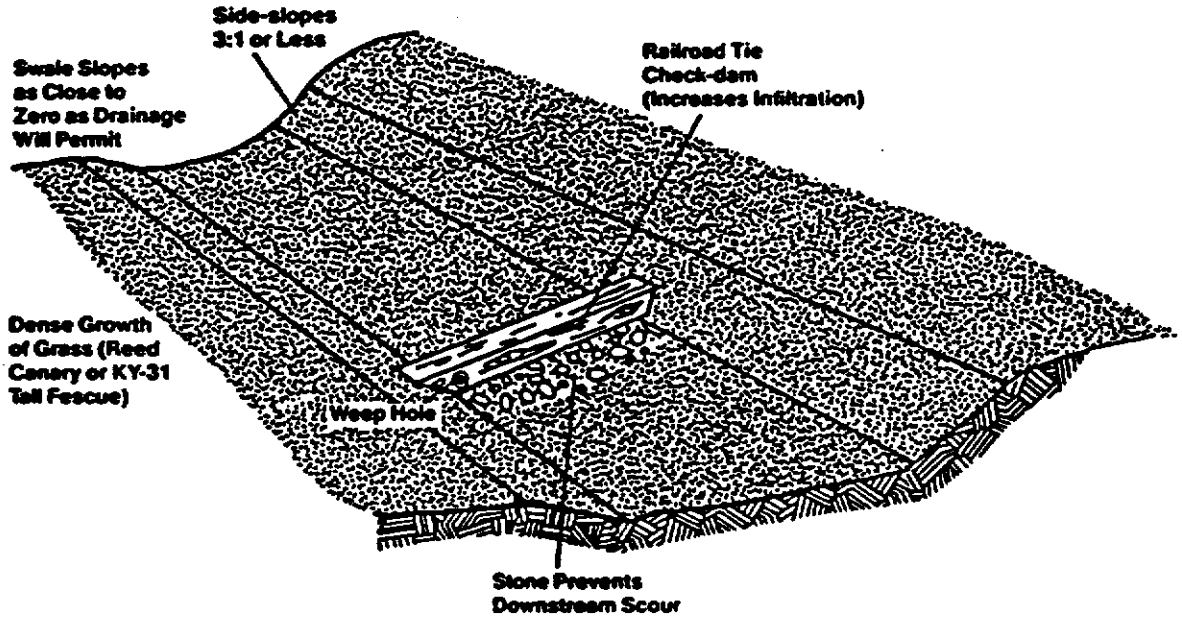
e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

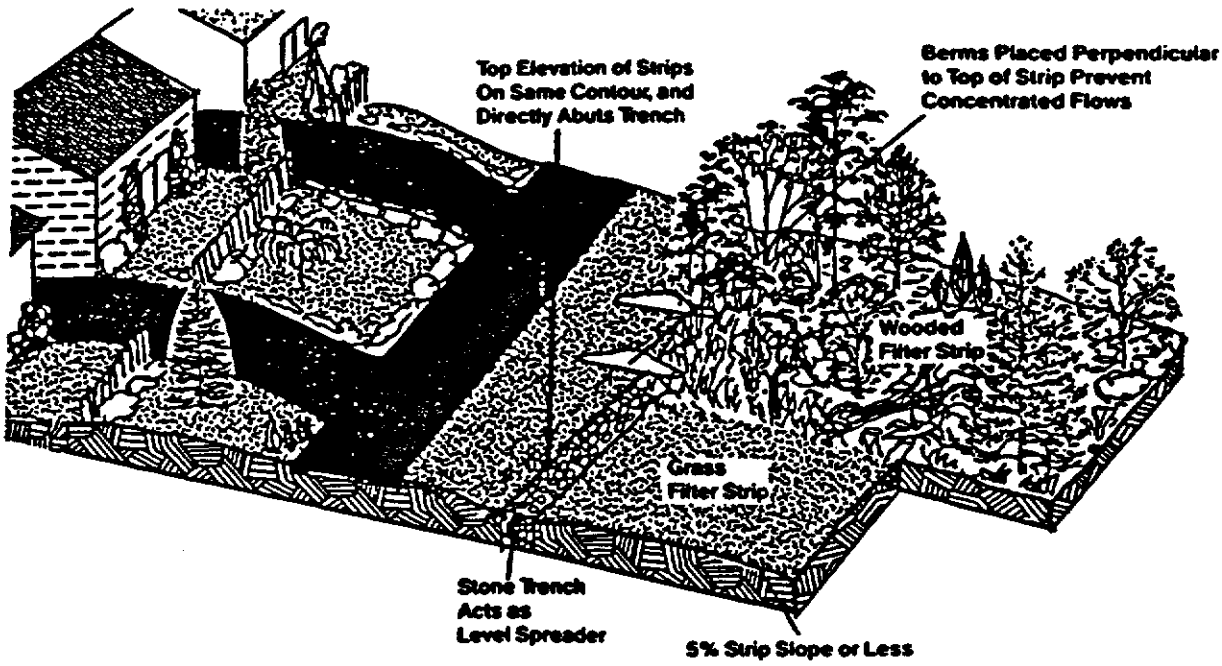
a. Reliability and Consistency over Time
   - Dependent on proper design and maintenance

b. Routine and Non-routine Maintenance
   - Routine maintenance; grass must be mowed, some litter removal, sediment removal to maintain channel flow capacity.
   - Non-routine maintenance: replacement of damaged grass.

c. Sustainability of Maintenance or Program Management
   - Maintenance must be included in the budget to insure proper operation.



Schematic of a Grassed Swale



Schematic of a Filter Strip

AUSTIN FIRST-FLUSH FILTRATION BASIN

DESCRIPTION:

This concept was first developed and required in Florida, and there are currently several hundred in use there and in Austin, Texas. They generally consist of a flow energy dissipator, an extended detention sedimentation chamber, a flow spreader device, a sand filter, and an underdrain outlet. The design tested by Veenhuis et al. (1988) was placed at the edge of a shopping center in Austin in the early 1980s. It is from this research and the extensive use of these filters in Austin that originally gave the basin its name. Shaver (1992) modified the design based on the Austin experience. The chamber has an inlet with trash grates that acts as a sedimentation trench. The stormwater then overflows into an adjacent filter chamber filled with sand. The water passes through the sand filter and into an outfall pipe, where it may be discharged to a storm sewer, another BMP, or receiving waters. The first-flush categorization refers to this BMP's design in treating the high pollutant levels associated with initial runoff volumes. (Note that the first-flush phenomena continues to be a subject of debate as to its significance. See Urbonas and Stahre, 1993.)

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - This BMP is applicable to tributary areas of one to 50 acres.

b. Typical Applications
   - The filter system is designed principally for runoff from impervious areas such as parking lots and commercial buildings. As such, it is typically an on-site BMP.
   - The design of the system is such that trapped solids from the sedimentation and filtration chambers are disposed of and not transferred to ground water.

c. Design Considerations
   - Typically designed as an off-line system
   - The drainage area must be kept small; using Delaware's regulations for hydraulic loading rates, Shaver sized the inlets for 5 acre drainage areas.

d. Other Experiences with BMP
   - The Austin design required the surface layer of sand to be cleaned out about once a year. An installation in Maryland using the Shaver designed was reportedly operated for 6 years before requiring maintenance.
   - The Austin Department of Public Works has found the removed sand and associated sediments are not toxic and may be landfilled.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Since neither the Austin or Shaver design rely upon infiltration, and suspended solids are actually removed from the system, this design is superior to others for ground water protection.

- Removal rates reported by Veenhuis et al., 1989:

Suspended Solids	60-80%
Total Phosphorus	60-80%
Total Nitrogen	(-110)-0%
Zinc	10-80%
Lead	60-80%
BOD	60-80%

- Shaver (1994) reports that some filters using sand with high iron content are showing TN and TP removals of 80%.

6. Demonstrated ability to accomplish secondary study objectives

- Above removal rates are based on outflow; generally, these provide very good mitigation of contaminants entering downstream waters.

ADVANTAGES:

- Pollutants are trapped and then removed from the system. Infiltration is not used to control runoff and pollution.
- Reported removal rates for TSS, total phosphorous, metals and BOD are moderate to high.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Concrete lined walls can present a safety hazard; fencing may be required.

b. Environmental Risk and Implications
   - Nitrogen levels appear to increase in the effluent.

c. Other
   - High capital cost for load-bearing filters (traffic areas).
   - Maintenance is required to removed clogged sand and accumulated sediment. In the Austin design, scraping of the top layer was necessary every year. In the Shaver design in Maryland, it was not needed for 6 years.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - The Austin design cost approximately $16,000 per acre of impervious watershed to install. Shaver (1994) currently budgets $20,000 per acre. Note that these are for load-bearing systems. When placed separately from vehicular traffic areas, costs are much lower than these estimates.

b. O&M Costs
   - Moderate

c. Longevity
- Unknown, but probably in excess of 20 years.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
- The high level of removal performance and minimal site impact should support this BMP's acceptability.

b. Equitability to Impacted Persons
- Construction costs can be substantial, and someone will have to bear the burden of financing (developer, property owner, taxpayers). This can be offset by a demonstration program that shows the BMP's effectiveness.

c. Amenity or Multi-Use Value
- Minimal

d. Fit with other Operations and Programs
- Must be incorporated into existing design and planing regulations

e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
- Austin data shows these filters are very reliable and there is no reason to expect decreased removal efficiencies.

b. Routine and Non-routine Maintenance
- Note the comments under disadvantages.
- Routine maintenance requires cleaning the sediment traps and removing the top 6" of sand. Non-routine maintenance consists of resanding (sand replacement) the filter when significant breakthrough occurs.

c. Sustainability of Maintenance or Program Management
- It is critical that routine maintenance be included in the budget.

SAND FILTERS

DESCRIPTION:

The general description of a sand filter actually encompasses a variety of designs, including the Delaware modification of the Austin first-flush filter described under that heading. In its simplest form, it is a self-contained bed of sand into which the first flush of runoff is diverted. The water is filtered as it passes through the sand, much like a slow sand filtration system for drinking water supply. The effluent is typically collected with perforated pipe and discharged to a stream or channel.

Follow-up sand filters are placed at the outlet of detention basins to improve effluent water quality. Enhanced sand filters use layers of peat, limestone, and/or topsoil to improve removal rates. Sand trench systems are used to treat parking lot runoff, and these include the Austin sand filter and the Shaver design. On the east coast, modified sand filters are found which look very much like a water quality inlet with a sand bed in the final stage.

A new modification of the sand filter concept is the biofiltration pond. Using a media which has a cation exchange capacity of at least 10 milli-equivalents per 100 grams will improve metals capture (WEI, 1994). Although sand is still the predominant media of choice, clays and other compounds may be included to attain high pollutant removal rates while still providing ample drainage for the design storm event. This can typically be accomplished using a gradation of filter media, decreasing in size with depth. Note that this is not an appropriate BMP for new development with associated erosion and sediment deposition.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Sand filters have been successfully used in diverse applications for small (less than 10 acres) tributary areas (Debo, 1994).
   - Recommended for "ultra-urban" areas where area is limited and runoff is poor quality; not recommended for new construction sites.

b. Typical Applications
   - Most sand filters are limited to an impervious tributary area of 5 to 10 acres. Follow-up sand filters, placed at the outlet of detention basins, may treat tributary areas in excess of 100 acres (Urbonas and Ruzzo, 1986).

c. Design Considerations
   - The primary purpose of the sand filter is to improve stormwater quality; they have a limited ability to reduce peak flows.
   - The retrofitting of sand filters has been performed in several applications (Schueler et al. 1992).

d. Other Experiences with BMP
   - Urbonas and Ruzzo (1986) developed a formula for the design of follow-up filters which was adopted for use by the city of Aurora, Colorado.

- Of the nearly 1000 sand filters installed since the early '80s in the Austin, Texas area, the vast majority are working to design specifications and very few have failed (Schueler et al., 1992)

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Note the removal rates for the Austin First-Flush Filter.
- The sand filter does not rely on infiltration to remove peak stormwater flows or improve effluent quality. At the same time it does appear to have good removal rates of most pollutants (with the possible exception of nitrogen), with the potential to increase removal efficiencies through the addition of other media such as peat, clays, limestone, and grass cover. The use of sand with high iron content also may improve efficiencies.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Similar to Austin First-Flush Filters.

ADVANTAGES:

- Since infiltration is not a significant mechanism, ground water protection is maximized.
- This BMP has a proven performance record in a variety of applications.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Basin should be grated to prevent unauthorized entry.

b. Environmental Risk and Implications
   - Since the removed sand has been demonstrated to be non-toxic, and there is no evidence that resuspension of contaminated sediment is a problem, there is little concern for environmental problems with this BMP.

c. Other
   - Larger sand filters with no vegetative cover may be unattractive; the surface can be extremely unattractive and some have caused odor problems.
   - Sand filters are primarily for stormwater quality mitigation, not quantity or peak flow mitigation.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - See the cost analysis under the Austin first-flush filter discussion.
   - Construction costs are estimated at $3 to $10 per cubic foot of runoff treated, or roughly 2-3 times the cost of a similarly sized infiltration

trench. Note that placing the sand filter outside of traffic zones reduces the need for high-strength cover grates.

b. O&M Costs
   - Routine and non-routine maintenance is generally less costly than an infiltration trench. Maintenance procedures do not require skilled labor, and non-routine maintenance is rare.

c. Longevity
   - Estimated at 20+ years

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Demonstration project is recommended (Schueler, 1992)

b. Equitability to Impacted Persons
   - Construction costs can be substantial, and someone will have to bear the burden of financing (developer, property owner, taxpayers). This can be offset by a demonstration program that shows the BMP's effectiveness.

c. Amenity or Multi-Use Value
   - Minimal

d. Fit with other Operations and Programs
   - Must be incorporated into existing design and planing regulations

e. Relationship to Federal, State or Local Requirements

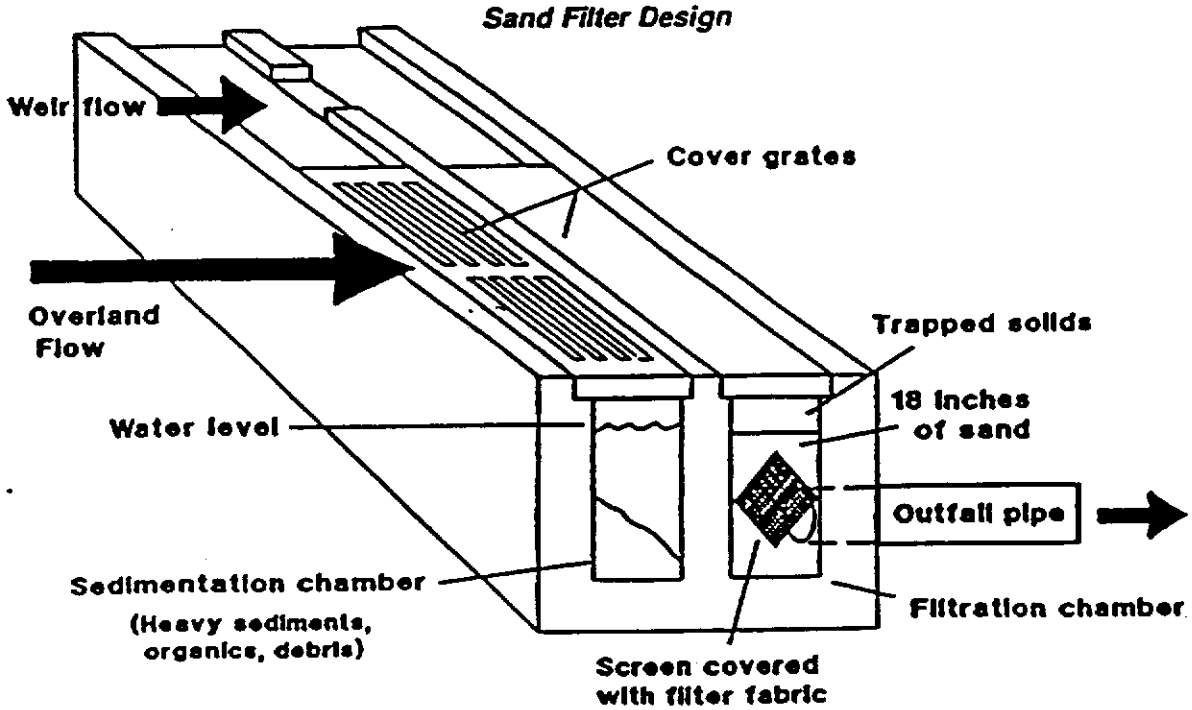
MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

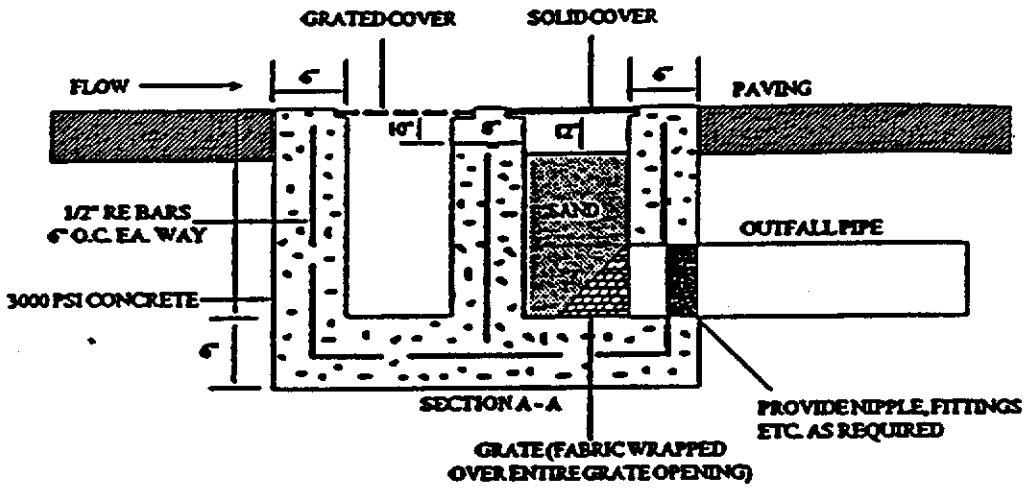
a. Reliability and Consistency over Time

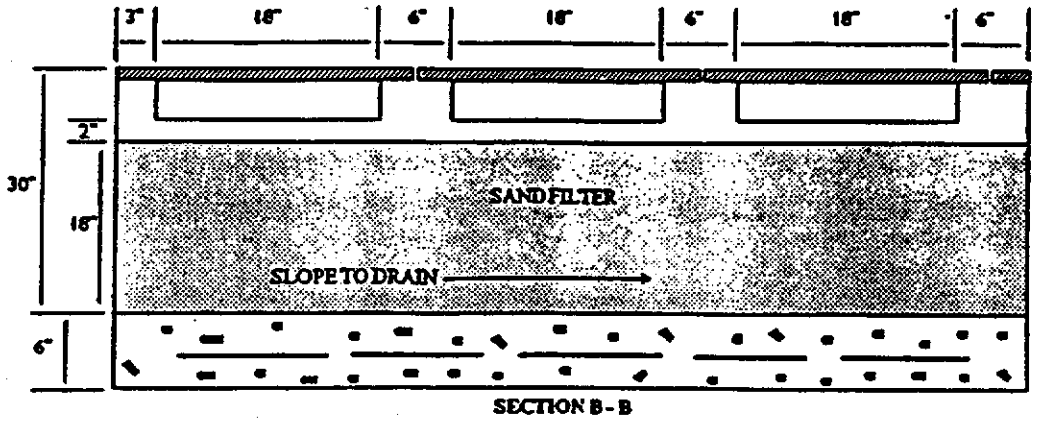
b. Routine and Non-routine Maintenance
   - The primary routine maintenance is debris removal and scraping of the upper sand layer. This is mostly manual work.
   - Nonroutine maintenance includes resanding (replacement of the sand) after enough sand has been removed that significant breakthrough occurs. In the case of the Shaver design in which a sedimentation basin is included, this must be cleaned out when the basin loses its holding capacity.

c. Sustainability of Maintenance or Program Management
   - Proper maintenance is critical to performance.

Sand Filter Design







EPA, 1992

INFILTRATION TRENCHES

DESCRIPTION:

Infiltration trenches can be generally described as a part of an open ditch that encourages rapid infiltration of runoff to the ground water through the placement of materials with high hydraulic conductivities. The trench is basically an excavated area within the ditch into which clean gravels are placed. The ditch should provide for slow flow rates to allow settling of suspended solids as well as the opportunity for substantial infiltration of the total intercepted flow.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - As an infiltration type BMP, use should be limited to those areas where ground water levels are well below the bottom of the trench and there is significant retention time in the soils before reaching ground water.

b. Typical Applications
   - Commonly, infiltration trenches are sized to intercept and dispose of runoff from a specific design storm (typically 2-year storms).

c. Design Considerations
   - To reduce clogging of the trench with sediments, a sump pit or a filter strip and flow spreader should be used to treat water entering the ditch.
   - Since infiltration is the primary mechanism for pollutant removal from runoff, the infiltration trench could actually impair ground water quality in fast-draining soils. Some biological uptake of nutrients may occur in well-vegetated ditches, and removal of sediments will remove some associated heavy metals.
   - The most important aspect to the potential for success of an infiltration trench is ground water levels. If the trench is easily inundated by high ground water levels or ground water mounding due to infiltration of runoff, the trench will simply become an open channel. Thus, the trench can fail in two modes; high infiltration rates to ground water that is near the base of the trench, or low infiltration rates due to poor draining soils or clogging of the trench with sediments.

d. Other Experiences with BMP
   - In a Maryland study (Galli, 1992) of 38 infiltration trenches, losses of infiltration capacity were caused by high water tables, poorly draining soils, and inadequately sized filter strips.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- As mentioned previously, the term 'infiltration trench' implies that runoff water is intercepted and directed to the ground water. Unless other BMPs are included to remove pollutants before the runoff enters the trench, ground water quality may be compromised. However, Urbonas and Stahre (1993) state that data

available so far shows that ground water quality does not degrade noticeably due to infiltration of stormwater from residential and many types of commercial developments. Filtration, adsorption, and ion exchange may occur in the underlying soils.

- Removal rates have been estimated by Schueler (1987) using assumed efficiencies and modeling. These show very high removal rates for TSS, Nitrogen, Phosphorous, Zinc and BOD. Field data supports these numbers indirectly by showing that a properly functioning trench can capture all storm runoff in 75% to 95% of all storms.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Actual data on mitigation is minimal. Note that Schueler's research is based on a high degree of infiltration, so that total flow to receiving waters is greatly reduced (unless ground water is directly recharging those same waters). This may or may not be an advantage, depending on the local hydrology.

ADVANTAGES:

- The combination of water conveyance, runoff reduction, lowering of peak flows, and pollutant removal make this an effective BMP.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Minimal

b. Environmental Risk and Implications
   - The use of infiltration as the primary pollutant reduction mechanism may increase ground water contamination by highly soluble contaminants in fast-draining soils and/or high water level conditions.

c. Other
   - If a trench becomes clogged with sediments, it simply stops functioning. The gravel must be removed and replaced with clean gravel, and it may be necessary to remove soils lining the trench which have also become clogged. The Maryland study (Galli, 1992) gave the following results for 38 trenches averaging 2.4 years old (maximum 5.1 years):

	Operating as designed?		
Pre-treatment type	Yes	No	Unknown
Sump Pit	48.4%	42.0%	9.6%
Grass Filter	42.9%	57.1%	0.0%
TOTAL	47.4%	44.7%	7.9%

- Conversely, a state survey of infiltration devices in Maryland in 1986 showed 80% of the infiltration trenches working as designed (Clement and

Pensyl, 1987). These results are questionable, however, as 50% of the trenches had no observation wells to determine if there was standing water under the gravel. Such trenches were reported as operating properly even though this primary evaluation criteria could not be determined.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Infiltration trenches are more costly than pond systems in terms of cost per unit runoff treated, but they are cost-effective in smaller sites where ponds cannot be used. Empirical data from a Washington D.C. study (Weigand et al. 1986) gives an empirical formula of;

     $\$ = 26.55^{*} (\text{Storage Volume})^{0.634}$;

     where $ = 1985 dollars and Storage Volume is in cubic feet, and greater than 10,000 cu. ft.

b. O&M Costs
   - Poorly maintained trenches will usually require costly rehabilitation or replacement to maintain functionality.

c. Longevity
   - Appears to be poor to fair; documented 50% failure rate in first five years

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Infiltration trenches are fairly unremarkable in terms of aesthetics, cost, and impact on the nearby residents.

b. Equitability to Impacted Persons
   - Cost of construction and maintenance is the primary impact.

c. Amenity or Multi-Use Value
   - Minimal

d. Fit with other Operations and Programs
   - Retrofitting into current sites may be difficult, but they can be readily implemented into planning and zoning.

e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

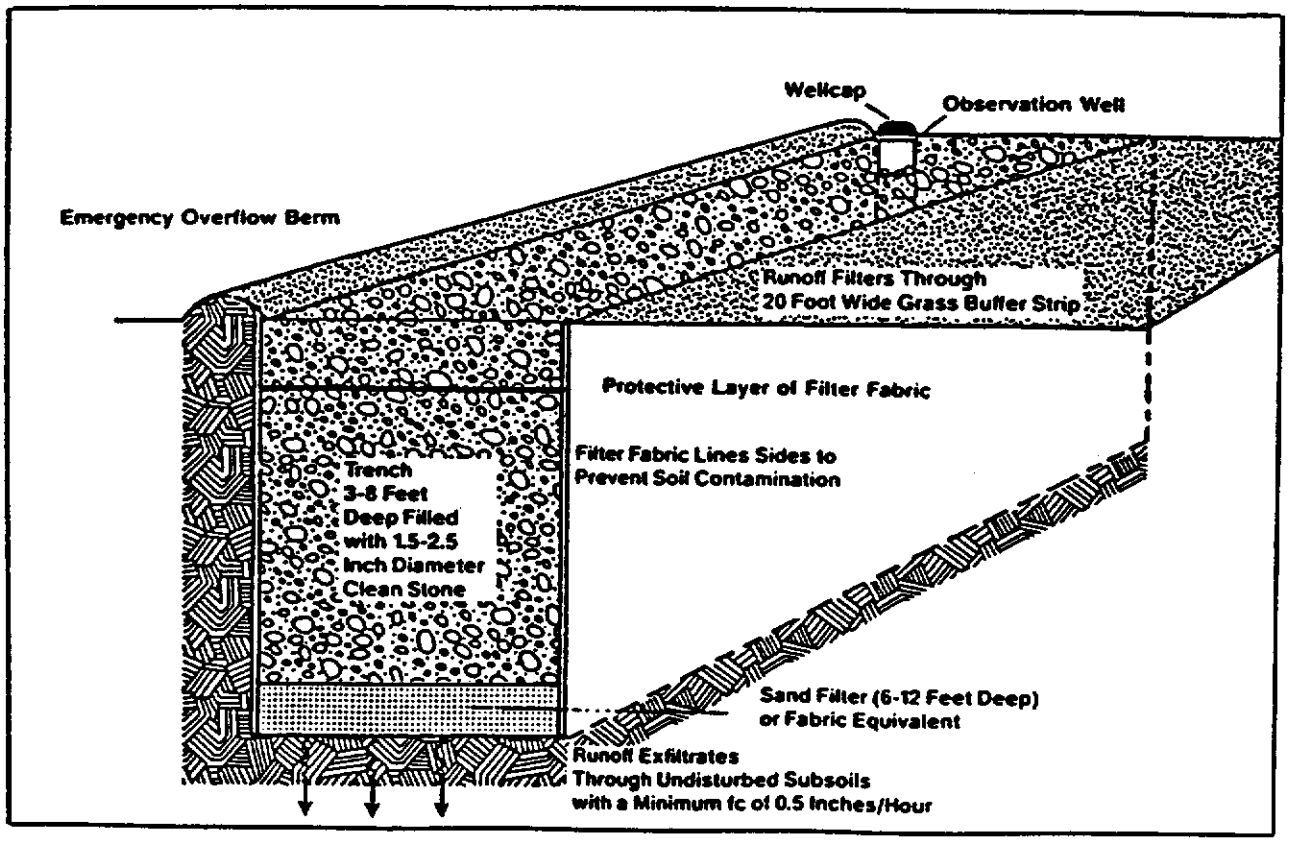
a. Reliability and Consistency over Time
   - If non-routine maintenance is performed correctly, there should be little degradation in performance

b. Routine and Non-routine Maintenance
   - Routine maintenance includes debris and litter removal and control of overgrown vegetation.
   - Non-routine maintenance involves a clogged trench which requires complete removal and replacement of the gravel as well as surrounding

clogged native soils. This can be greatly reduced by proper design and routine maintenance.

c. Sustainability of Maintenance or Program Management

- If the trench becomes fully clogged, complete rehabilitation may cost as much as initial construction; if funding is private, the trench may go unrepaired.



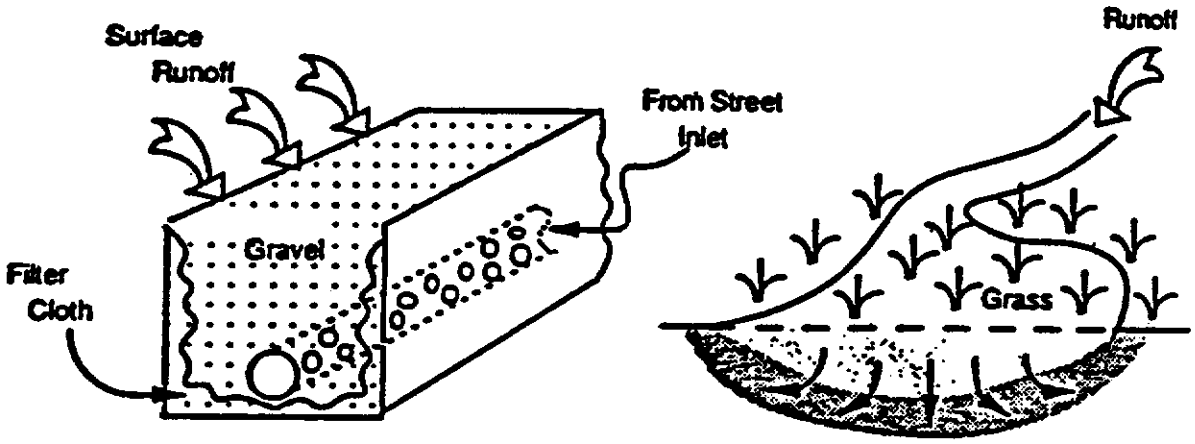
Schematic of an Infiltration Trench

—Estimated long-term pollutant removal rates (percent) for infiltration basins.

POLLUTANT	SIZED BASED ON		
	0.5-IN RUNOFF/IMPERV. ACRE	RUNOFF FROM 1-IN RAIN	2-YEAR STORM RUNOFF VOLUME
Total suspended solids	75	90	99
Total phosphorus	50-55	60-70	65-75
Total nitrogen	45-55	55-60	60-70
Metals	75-80	85-90	95-99
Biochemical oxygen demand	70	80	90
Bacteria	75	90	98

Source: Schueler, 1987.

INFILTRATION DEVICES



- EFFICIENCY: EXCELLENT (Small depressional infiltration basins are great onsite controls)
- FUNCTION: INFILTRATES RUNOFF TO GROUNDWATER, SOIL FILTERS POLLUTANTS
- MAINTENANCE INTENSIVE (Mowing, upstream erosion control)
- NON-FUNCTIONAL IF PLUGGED
- SOIL MUST BE HIGHLY PERMEABLE, AND WET SEASON WATER TABLE 3 FT. BELOW BOTTOM
- EXPERIENCE WITH UNDER-DRAINED INFILTRATION BASINS IS POOR

ASCE 1990-91

INFILTRATION BASINS

DESCRIPTION:

Infiltration basins are made by constructing an embankment or excavating down to relatively permeable soils. The basin stores stormwater until it infiltrates through the sides and bottom of the basin. As an infiltration device, they also act to recharge ground water.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - As an infiltration type BMP, use should be limited to those areas where ground water levels are well below the bottom of the basin and there is significant retention time in the soils before reaching ground water.

b. Typical Applications
   - Commonly, infiltration basins are sized to intercept and dispose of runoff from a specific design storm (typically 2-year storms).

c. Design Considerations
   - Since infiltration is the primary mechanism for pollutant removal from runoff, the infiltration basin could actually impair ground water quality in fast-draining soils. It is therefore recommended that a dense turf of water tolerant grass be used on the side slopes and bottom of the basin (Livingston, 1994). This provides filtration and removal of dissolved solids, nutrients and metals.
   - The most important aspect to the potential for success of an infiltration basin is ground water levels. If the basin is easily inundated by high ground water levels or ground water mounding due to infiltration of runoff, the basin will simply become an open channel. Thus, the basin can fail in two modes; high infiltration rates to ground water that is near the base of the basin, or low infiltration rates due to poor draining soils or clogging of the basin with sediments.
   - Several studies of infiltration basins have shown a significant percentage (40-60%) of basins studied showed losses of infiltration capacity caused by poor design and construction, upstream erosion, and inadequate maintenance.

d. Other Experiences with BMP
   - Infiltration basins can be very effective at pollutant removal, and they can be completely useless at this task. The difference is primarily the result of the previous statement as to proper design, construction, and maintenance. Additionally, they cannot be used in all soil types or water tables. Careful consideration of these criteria is needed to insure a successful installation.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- As mentioned previously, the term 'infiltration basin' implies that runoff water is intercepted and directed to the ground water. The use of vegetation to trap suspended solids, metals, and nutrients is key to ground water protection. Filtration, adsorption, and ion exchange may occur in the underlying soils.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Actual data on mitigation is not easy to produce, as there should be no effluent to sample if the basin is working properly. Instead, one can assume that if the design retains 90% of the water from all storm events, removal efficiency should be at least 90%. This may or may not be true, as a very large event could resuspend trapped sediments and flush them from the basin. Again, proper function of the basin is key to pollutant removal.

ADVANTAGES:

- The combination of water conveyance, runoff reduction, lowering of peak flows, and pollutant removal make this an effective BMP.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Possible drownings during and after storm events.

b. Environmental Risk and Implications
   - The use of infiltration as the primary pollutant reduction mechanism may increase ground water contamination by highly soluble contaminants in fast-draining soils and/or high water level conditions.

c. Other
   - Infiltration capacity will decrease with time. If a basin becomes clogged with sediments, it simply stops functioning. It may be necessary to remove soils lining the basin which have become clogged. If the original infiltration rates were overestimated, underdrains may be needed.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Capital costs are generally similar to wet detention basins, but they are also highly variable depending on site selection, soil types, and configuration.

b. O&M Costs
   - Poorly maintained basins will usually require costly rehabilitation or replacement to maintain functionality.

c. Longevity
   - Appears to be poor to fair; documented 40 to 60% failure rate in first few years, and as high as a 40% failure rate immediately after construction.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - As with any pond, a large areal requirement can be a problem.

b. Equitability to Impacted Persons
   - Cost of construction and maintenance and areal requirements are the primary impact.

c. Amenity or Multi-Use Value
   - Infiltration basins can be used for soccer fields, open areas, etc.

d. Fit with other Operations and Programs
   - Retrofitting into current sites may be difficult, but they can be readily implemented into planning and zoning.

e. Relationship to Federal, State or Local Requirements

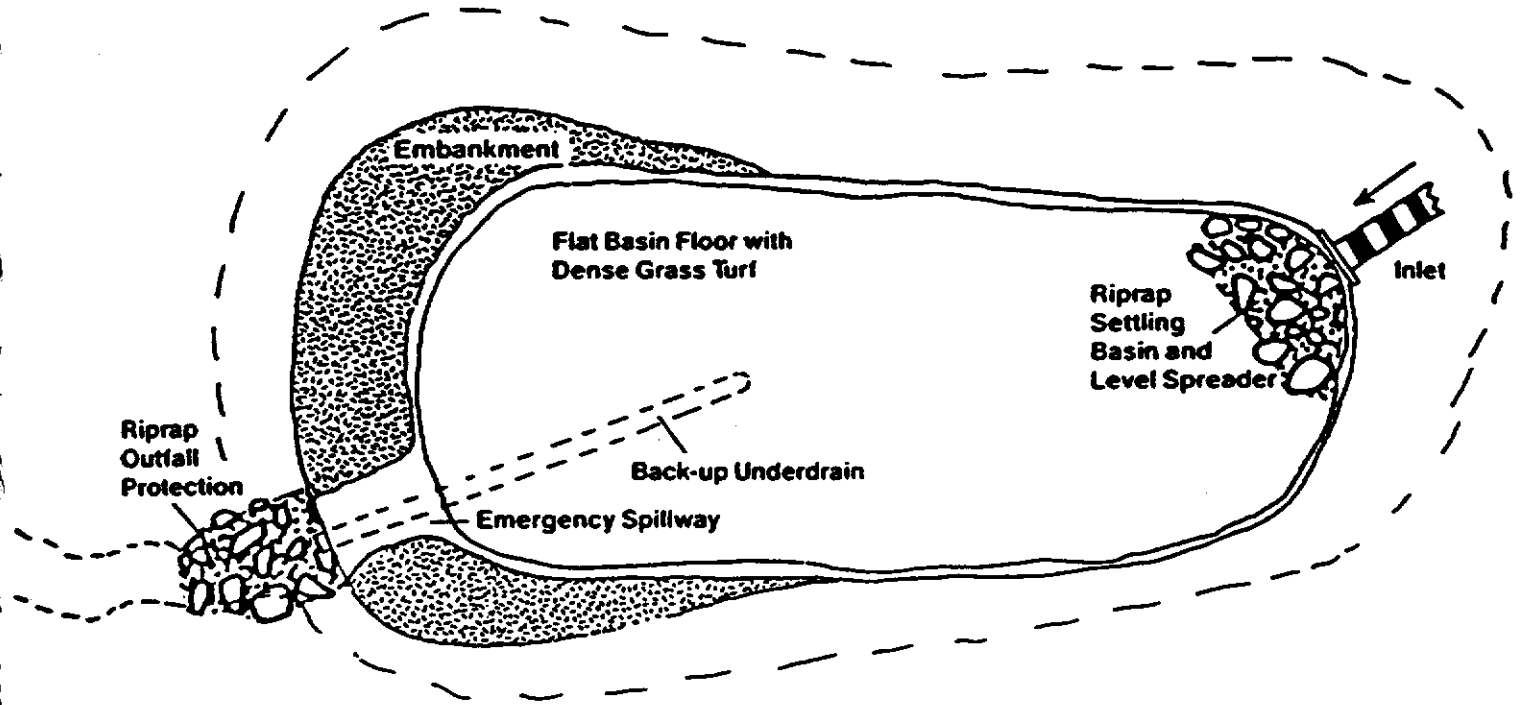
MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

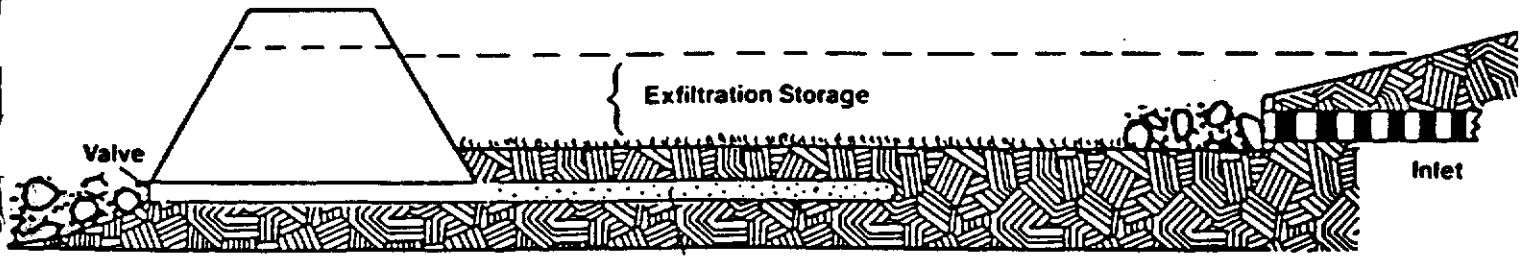
a. Reliability and Consistency over Time
   - If non-routine maintenance is performed correctly, there will still be degradation in performance. This can be minimized with proper design and upstream protection.

b. Routine and Non-routine Maintenance
   - Routine maintenance includes debris and litter removal and control of overgrown vegetation. Livingston (1994) recommends deep tilling of the soils every 5 to 10 years to break up clogged surface layers.
   - Non-routine maintenance involves installation of new soils or underdrains where infiltration rates cannot be brought up to design needs through routine maintenance.

c. Sustainability of Maintenance or Program Management
   - If the basin becomes fully clogged, complete rehabilitation may be very expensive; if funding is private, the basin may go unrepaired.

Schematic of an Infiltration Basin

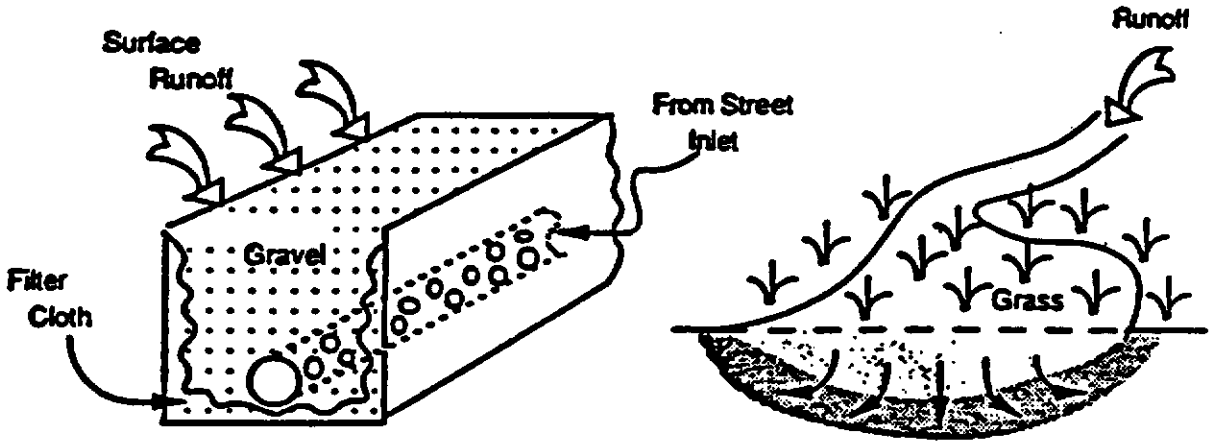




Back-up Underdrain Pipe in Case of Standing Water Problems

SCHUELER, 1987

INFILTRATION DEVICES



- EFFICIENCY: EXCELLENT (Small depressional infiltration basins are great onsite controls)
- FUNCTION: INFILTRATES RUNOFF TO GROUNDWATER, SOIL FILTERS POLLUTANTS
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- EXPERIENCE WITH UNDER-DRAINED INFILTRATION BASINS IS POOR

ASCE 1990-91

POROUS PAVEMENT

DESCRIPTION:

There are two forms of porous pavement: modular block, which is made porous through its structure, and poured-in-place concrete or asphalt which is porous due to the mix of the materials.

Modular block porous pavement consists of perforated concrete slab units underlain with gravel. The surface perforations are filled with coarse sand or sandy turf. It is used in low traffic areas to accommodate vehicles while facilitating stormwater runoff at the source. It should be placed in a concrete grid that restricts horizontal movement of infiltrated water through the underlying gravels.

Poured-in-place porous concrete or asphalt is generally placed over a substantial layer of granular base (Urbonas and Stahre, 1993). The pavement is similar to conventional materials, except for the elimination of sand and fines from the mix.

If infiltration to ground water is not desired, a liner may be used along with perforated pipe and a flow regulator to slowly drain the water away over a 6 to 12 hour period.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - See Design Considerations.
   - This is exclusively an on-site BMP that should never be used for treating water with high sediment loads. This is particularly true for porous concrete or asphalt, which are primarily designed to remove pollutants deposited on the pavements from the atmosphere (Schueler, 1987)

b. Typical Applications
   - Modular block pavement is applicable to low traffic zones and permeable upper soils with ground water no less than 4 feet from the gravel bedding.
   - The use of porous concrete or asphalt is not well-received in colder climates where freeze-thaw cycles may fracture the pavement. Despite this, it has been found that properly designed systems are not damaged by such processes (Debo, 1994).

c. Design Considerations
   - Either form of porous pavement must be limited to low traffic areas with limited deposition of clays and fines which could clog the pavement.
   - As infiltration is the primary mechanism of pollutant removal, areas with high ground water vulnerability may not be good choices for this BMP.
   - Large soil surface areas are needed for maximum exfiltration and pollutant removal.

d. Other Experiences with BMP

- Modular block BMPs have been in use since the mid-1970's. Field data is lacking to quantify long-term performance as an infiltration device, but anecdotal evidence indicates it is reliable. Pratt (1990) found that if excessive sediment deposition is controlled, modular paved surfaces can function for at least 15 years.
- Anecdotal experience indicates that unless careful cleaning with vacuum cleaners is performed on a frequent basis, porous pavement will seal within 1-3 years. Ultimately, it will seal anyway and cannot be repaired; the only option appears to be replacement. (Urbonas and Stahre, 1993). Porous pavement sites have one of the highest failure rates of any BMP. At the same time, when working properly it can be a very cost-effective BMP for commercial sites.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- As infiltration is a primary mechanism, the potential for pollutant discharge to ground water, particularly soluble pollutants, is significant. Additionally, there is concern that hydrocarbons may be leached from asphalt material, thereby increasing the contaminant load.

- No specific field data is available on pollutant removal rates. Suspended sediment and associated metals, oil and grease removal may be high, as long as the pavement remains porous. Removal rates estimates vary from 0 - 95%. Soluble constituent removal is likely lower, depending on the materials used. Filtration, adsorption, and ion exchange may occur in the underlying soils. With good drainage, soluble constituents are likely to show low removal efficiencies. (UDFCD, 1992)

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- As noted above, removal rate data is minimal. As with infiltration trenches, the key to pollutant removal may be the minimization of off-site flow. Secondary BMPs will be needed to further mitigate pollutant problems.

ADVANTAGES:

- Low maintenance for modular block pavement.
- Slows and reduces runoff, reducing the need for expensive detention facilities.
- Safety: decreased wet weather skidding, hydroplaning and headlight reflection glare.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Note comments under advantages as to safety issues.

b. Environmental Risk and Implications

- Fast draining soils can encourage ground water pollution from soluble metals and other pollutants.
- Risk can vary from very minor to great, depending on how well the system is functioning

c. Other

- Large silt and sand loads (e.g. from construction sites) may accelerate the clogging of the pavement pores, requiring expensive removal of sediments.
- Porous concrete or asphalt tends to seal in 1-3 years unless vacuum cleaning is done frequently; even then, it will eventually seal. The need for vacuum cleaning makes this option more expensive for routine maintenance.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs

- Moderate capital cost per acre served (UDFCD). Schueler (1987) notes that only incremental costs over a conventional parking lot should be considered, since this is only a modification to an already needed facility.

b. O&M Costs

- Moderate routine O&M costs (vacuum cleaning), high non-routine costs, particularly for porous concrete and asphalt; for these, replacement may be needed within a few years.

c. Longevity

- High failure rates, highest for porous asphalt or concrete

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership

- Use of porous pavement is constrained to deep and pervious soils, restricted traffic (light automobile and pedestrian traffic only). Use in outlying parking areas or low-traffic areas would be the best use of this BMP.
- Decreased wet weather skidding, hydroplaning and headlight reflection glare make porous asphalt marketable from the standpoint of traffic safety (Schueler, 1987). In a typical parking lot situation however, these are minor issues.

b. Equitability to Impacted Persons

- The maintenance of the BMP can be a considerable burden to a private property owner. Initial costs, however, should not be substantially greater than conventional pavement.

c. Amenity or Multi-Use Value

- By definition, this BMP has a multi-use value.

d. Fit with other Operations and Programs

- This cannot be readily retrofit; can be used for new sites.

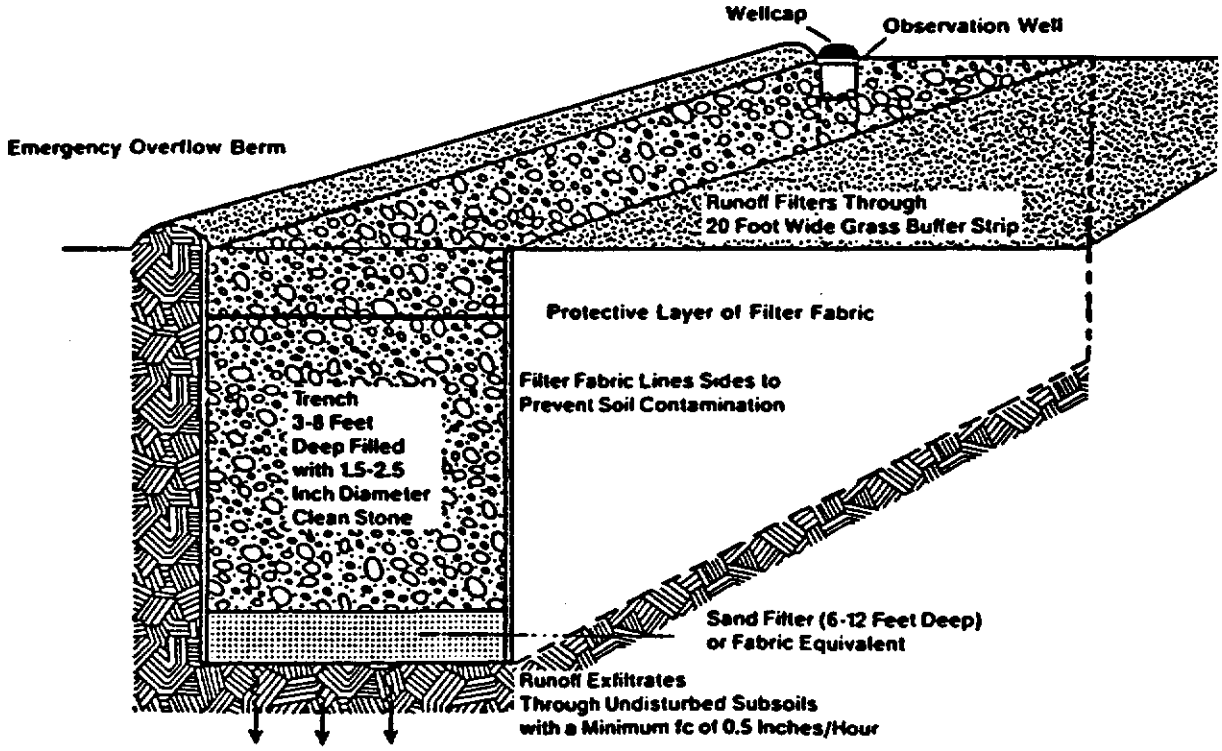
e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - All porous pavement designs will degrade in performance over time, with careful maintenance only incrementally increasing its operational lifespan.

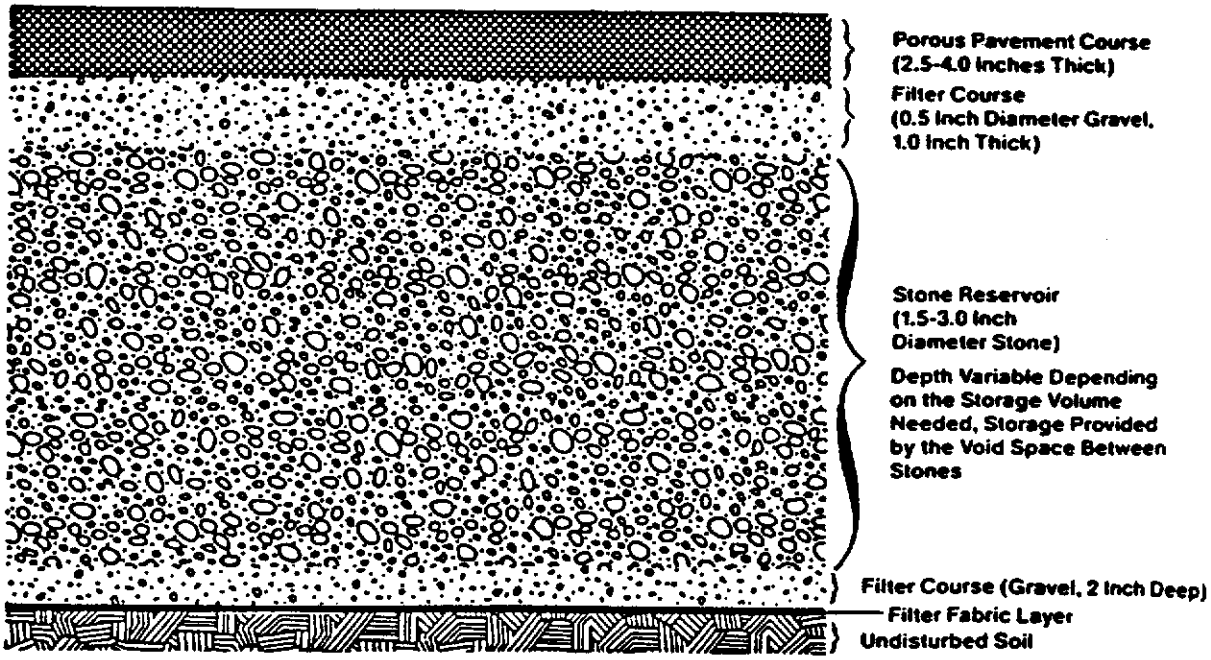
b. Routine and Non-routine Maintenance
   - Maintenance is minimal for modular block except when the surface becomes clogged. This will require expensive nonroutine maintenance in the form of removing the blocks and the underlying clogged gravels. Routine (quarterly) vacuum sweeping and high pressure water washing of porous asphalt is required to prevent clogging. Nonroutine maintenance consists of complete replacement, and may be required in as little as one year's time.
   - When turf is used with modular block, lawn care maintenance is needed.

c. Sustainability of Maintenance or Program Management
   - The obvious limitation is the need for expensive nonroutine repairs or replacement. If privately owned, this expense may preclude necessary work. If publicly owned, there may be insufficient funds budgeted for maintenance.



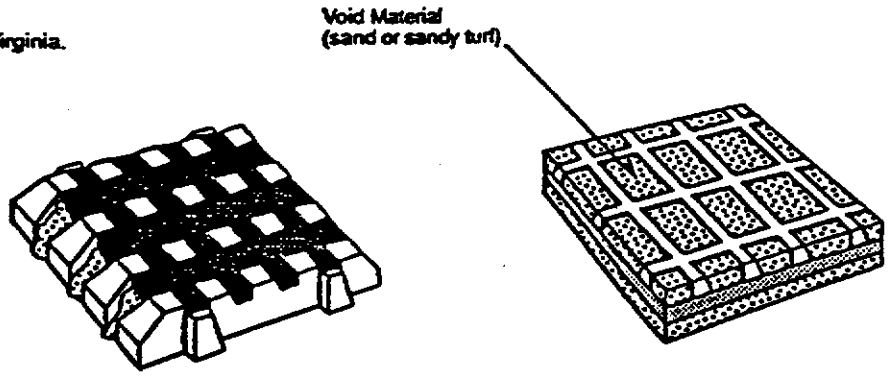
Schematic of an Infiltration Trench

Side View

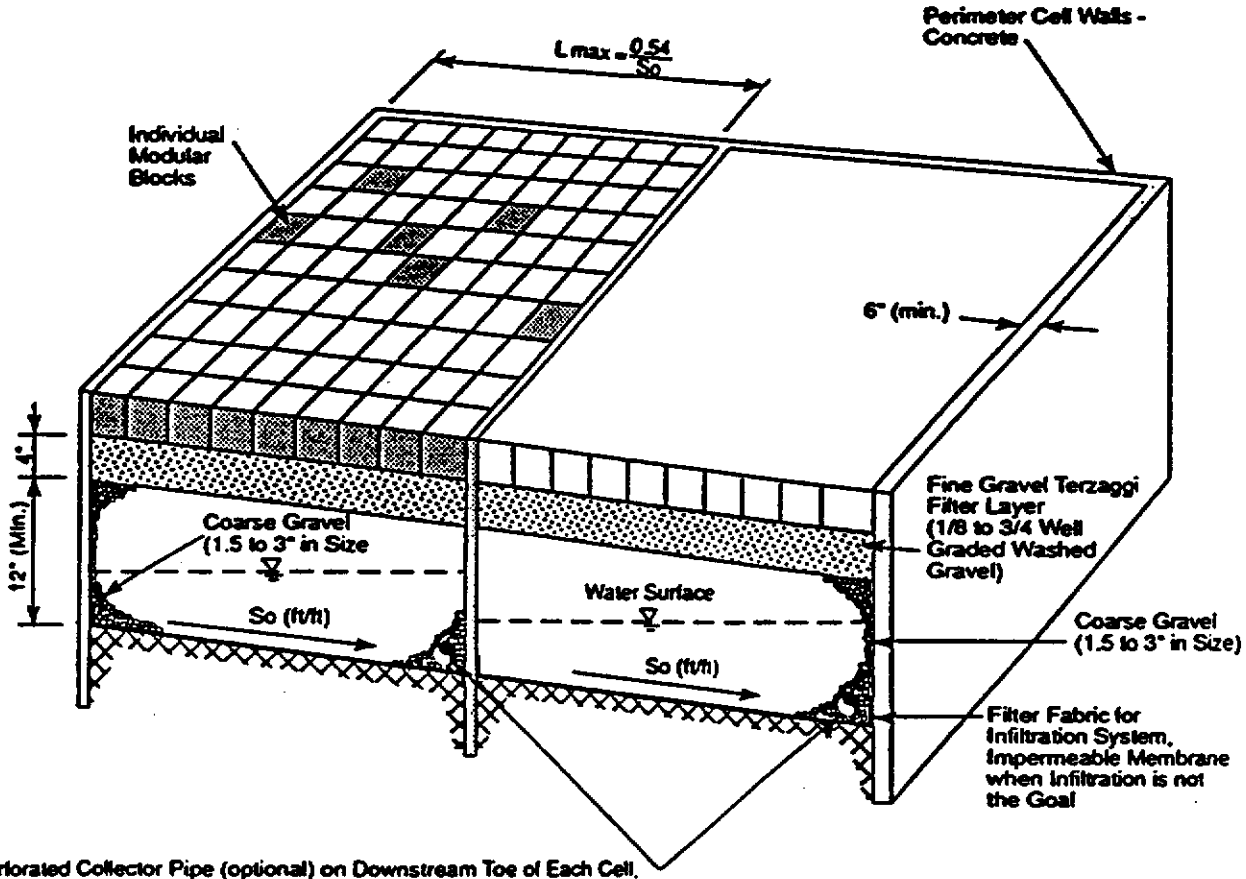


Schematic of Typical Porous Pavement Section

Source: State of Virginia.



TWO EXAMPLES OF INDIVIDUAL CONCRETE MODULAR PAVING BLOCK



Perforated Collector Pipe (optional) on Downstream Toe of Each Cell, Connected to an Outfall Pipe. Use only when Infiltration is not Possible or Desired. Each cell's collector Pipe should have a Constricted Outlet to limit the drainage of the pore space volume in the Coarse Gravel Layer in 12-hours.

PERSPECTIVE OF SIDE-BY-SIDE MODULAR BLOCK CELLS

MODULAR BLOCK POROUS PAVEMENT

OIL/GRIT SEPARATORS

DESCRIPTION:

- Also known as a Water Quality Inlet, this is a three-stage underground retention system designed to remove heavy particulates and hydrocarbons from runoff. The first chamber allows for sedimentation. The second chamber has an inverted elbow for an outlet, such that oil is trapped at the surface. The third chamber directs the water out.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - This BMP was originally designed for industrial applications, rather than urban stormwater applications. When translating to a stormwater BMP, two problems arise:
     - an expectation of removal of pollutants other than oil and grit is created;
     - widely varied flows can overwhelm and make ineffective a BMP that was designed for steady low flows and not "flashy" high flows.
   - The most effective use of this BMP is in capturing runoff from small, high density sites where high concentrations of oils in runoff are expected.

b. Typical Applications
   - Oil/Grit separators are most frequently used in highly urbanized areas where other BMPs cannot be used due to space limitations. Note comments above.

c. Design Considerations
   - Tributary area is usually limited to two acres or less of mostly impervious surfaces. This is primarily a water quality rather than quantity mitigation BMP.

d. Other Experiences with BMP
   - Experience demonstrates that these have limited pollutant removal ability with resuspension of trapped particulates common. Since residues tend to be toxic, disposal is a problem. As a result, there are no current clean-out and disposal procedures.
   - The Maryland study (Galli, 1992) concluded that oil/grit separators should not be employed as BMPs in Prince George's County until design and maintenance problems can be resolved. Due to the fact that toxic wastes are generated by these, this recommendation should be considered in any locale.

DEMONSTRATED ABILITY TO PROTECT Groundwater QUALITY:

- Pollutant removal ability is limited. This is due to the lack of clean-out and disposal procedures and the tendency for trapped sediments to resuspend. One

study (Shepp et al. 1992) showed that the depth of trapped sediments in over 120 separators was less than two inches. More than eighty percent of the sediments were coarse-grained grit and organic matter. Additionally, the amount of trapped sediment did not correlate with age, indicating that resuspension is a common failure mode. Sediments that were trapped were very oily in nature.

- The positive aspect to this BMP is that examination of the sediments shows that the adsorbed pollutants match those found in receiving water bodies, indicating that the right target pollutants are being addressed.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- When working properly, this can be an effective tool to reduce urban pollutant loads to receiving waters. However, due to the difficulties in maintaining the chamber, a sand filter may be a better choice.

ADVANTAGES:

- Can be used in highly urbanized areas where other BMPs cannot be used.
- Trapping of floatable trash and debris and possible reduction of hydrocarbon loadings from impervious areas.
- They do not rely on infiltration, so that direct input of runoff into the ground water is unlikely.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - The trapped sediments are often highly toxic (hydrocarbons).

b. Environmental Risk and Implications
   - Trapped sediments are highly toxic and cannot be easily disposed of, resulting in the generation of a toxic waste.
   - Large storm events can cause resuspension of trapped solids, resulting in a pulse of very poor quality effluent.

c. Other
   - The lack of a practical disposal method for the toxic sediments results in improper maintenance that causes failure of the system.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Capital costs are $10 to $40 per cubic foot of runoff treated.

b. O&M Costs
   - Maintenance costs would be extremely high if performed; consequently, it is not performed.

c. Longevity

- System longevity is probably in excess of 20 years; however, pollutant removal may only persist for a matter of months.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - The problems associated with sediment disposal, toxic hazards, and system inefficiency do not make this BMP a good choice for a semi-urban environment with predominantly low population and commercial densities.

b. Equitability to Impacted Persons
   - If the toxicity problem can be solved, this would be a low-impact BMP. Currently, this is not the case.

c. Amenity or Multi-Use Value
   - None.

d. Fit with other Operations and Programs
   - For the reasons described, this BMP is a poor fit with existing programs.

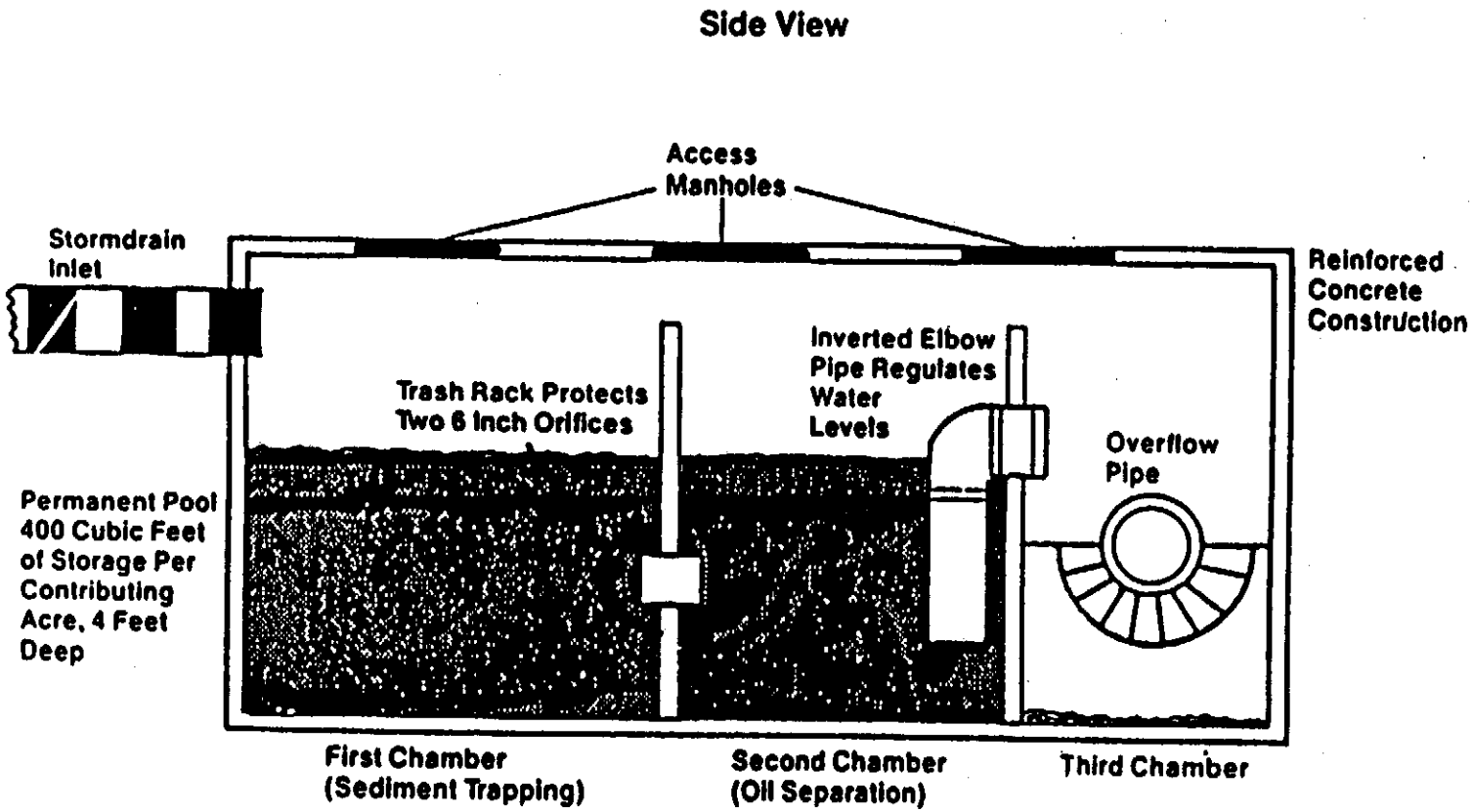
e. Relationship to Federal, State or Local Requirements
   - Toxic sediments eliminate landfilling as a disposal option.

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - Pollutant removal performance likely drops off very quickly after a few months.

b. Routine and Non-routine Maintenance
   - Sediments are toxic and cannot be landfilled; therefore, maintenance involves only the removal of floatables.

c. Sustainability of Maintenance or Program Management
   - Currently, this is the fatal flaw for many oil/grit separators in use. The unit cannot be maintained because of the problem with disposing of accumulated sediment.



Schematic of a Water Quality Inlet, Montgomery County, MD.
Three Chamber Design

SCHUELER, 1987

CONVENTIONAL CATCH BASINS

DESCRIPTION:

These are the typical installations that have been used for many years to capture storm water runoff and divert it to a stormwater conveyance system. It is simply a basin, typically made of concrete, which collects and then immediately directs the water into the sewer system.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Catch basins are used primarily in developed areas to collect stormwater runoff from impervious areas.

b. Typical Applications
   - Curb and Gutter designs

c. Design Considerations
   - Standard hydraulic analyses are used to design the basin.

d. Other Experiences with BMP
   - Widely used, they offer virtually no pollutant abatement.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Other than the fact that there is no infiltration to the ground water, conventional catch basins have no measurable pollutant removal capacity.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Virtually none. Water is simply collected and typically routed to receiving waters with no water quality mitigation.

ADVANTAGES:

- This is a common and easily designed BMP with many years of experience.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - There are many anecdotal accounts of accidental drownings and trapped children.

b. Environmental Risk and Implications
   - Since the basin assists in directly routing runoff to receiving bodies with no pollutant attenuation, they represent a significant environmental risk.

c. Other
   - Peak flows are not well mitigated, unless they are used in conjunction with some other BMP.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - The cost of this common BMP is best evaluated by local agencies who have significant experience in their design and construction in the area.

b. O&M Costs
   - Minimal

c. Longevity
   20+ years

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - The public is familiar and therefore comfortable with these basins, but the need for increased pollutant removal may make this BMP less acceptable over time.

b. Equitability to Impacted Persons
   - Other than capital costs, impact is minimal.

c. Amenity or Multi-Use Value
   - The only "multi-use value" to catch basins is the opportunity for individuals to conveniently dispose of toxic or hazardous liquids while avoiding expensive proper disposal fees or prosecution for illegal dumping. This is a common and well-know problem in every community.

d. Fit with other Operations and Programs
   - Because of its simplicity and universal use, this BMP fits well with existing plans.

e. Relationship to Federal, State or Local Requirements
   - Increased federal emphasis on urban non-point source pollution will continue to be directed at designs and practices such as these that do not function well in mitigating water quality problems.

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - Performance may be limited due to collections of debris at the inlet. Unfortunately, such debris is most likely to collect during large storm events, causing the basin to fail when it is most needed.

b. Routine and Non-routine Maintenance
   - Maintenance consists of non-routine cleaning of debris blocking the inlet.

c. Sustainability of Maintenance or Program Management
   - Since maintenance is minimal, this is rarely a problem.

CATCH BASIN INSERTS

DESCRIPTION:

These are a newer type of oil/grit separator consisting of an insert that fits inside a standard catch basin. Normally the inserts are made of a stainless steel, aluminum or cast iron framework which sits on the lip of the inlet grate frame and hangs down into the catch basin inlet chamber. One or more trays of filtration media are placed into the framework. The top screen or tray is usually a sediment trap. The flow enters the top of the filtration tray and filters through. Filtering media can be made of activated charcoal (for pesticides, fertilizer and metals removal), reconstituted wood fiber (primarily for oil and grease) or household fiberglass insulation. Excess flow beyond the capacity of the media bed or due to media clogging is routed over the sides of the tray(s) and out through the bottom or side of the framework. The capacity of the overflow is designed to equal or exceed the capacity of the grate.

One or more trays of filtering media, sometimes of different types, are then placed either stacked or in a rack below the sediment trap and screen. The media can be disposed in a manner similar to oil and grit chamber sediment though it may need to be tested once to see if it is a hazardous waste.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - These can be used in most places where catch basins are installed.

b. Typical Applications
   - It appears to be an ideal application for retrofitting such areas as parking lots, gas stations, vehicle maintenance areas, "dirty" neighborhoods or industrial areas, etc.

c. Design Considerations
   - Several companies produce such inserts, or they can be fabricated from common materials. The materials which make up the framework and the trays should be highly resistant to corrosion, easy to install manually and fit standard inlets.

d. Other Experiences with BMP
   - Not widely implemented as yet, so little can be inferred from other experiences.

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Pollutant removal rate information is limited to a few installations, some bench tests and visual inspections. But it appears to be quite high for oil and grease and metals (above 80%-90%) (Debo, 1994).

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Unknown, but from a design aspect this appears to be a potentially valuable BMP, particularly for retrofitting.

ADVANTAGES:

- It is easy to install (may take as little as 15 minutes), relatively inexpensive, requires no construction or modifications of existing catch basins, easy to maintain by property owners, and is targeted toward the major pollutants from these areas.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Similar to conventional catch basins

b. Environmental Risk and Implications
   - Difficult to quantify, but should be significantly improved over conventional basins

c. Other
   - Possible fouling by debris.
   - Lack of experience means that unknown problems could exist that have not yet been documented.

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Installation costs range from about $400 to $2000 per catch basin depending on the complexity of the tray arrangement and the types of pollutants desired to be removed.

b. O&M Costs
   - Costs for replacement media are less than $25 per installation and must be replaced periodically depending on the climate and site conditions. Some media can be cleaned and reused.

c. Longevity
   - Unknown, since these devices are so new.

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Ease of installation, performance increase and lack of a need for property to be set aside are positive aspects; unproven reliability, performance and maintenance protocols are negatives.

b. Equitability to Impacted Persons
   - Ease of maintenance, low cost, and lack of negative impacts should make this BMP equitable.

c. Amenity or Multi-Use Value

- Functions with existing storm sewer designs.

d. Fit with other Operations and Programs
   - Fits well with traditional catch basin design and usage.

e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - Unknown, but proper maintenance should provide a reasonable lifetime vs. costs. There is some question concerning the chemical integrity and longevity of the fiberglass in harsher environments.

b. Routine and Non-routine Maintenance
   - Maintenance requirements include inspecting the flow integrity of the system and replacement of the filtration media. Quarterly replacement is a good starting estimate though the installations should be checked after wet periods and periodically.

c. Sustainability of Maintenance or Program Management
   - Routine maintenance is required and must be built into the cost estimate for the system.

REGULAR DETENTION BASINS

DESCRIPTION:

Regular Detention Basins are simple collection basins that reduce peak flows by holding runoff for a short period of time. Pollutant removal is not a primary design criteria.

GENERAL APPLICABILITY AND EXPERIENCE WITH BMP ELSEWHERE:

a. Ability to be Applied Universally Throughout the Municipality, or on a Specific Watershed Basis
   - Minimal usefulness for water quality mitigation.

b. Typical Applications
   - Peak flow control only

c. Design Considerations

d. Other Experiences with BMP

DEMONSTRATED ABILITY TO PROTECT GROUND WATER QUALITY:

- Protection of water quality is not a primary design criteria. Detention times are typically far too short to provide significant settling of suspended sediments.

DEMONSTRATED ABILITY TO ACCOMPLISH SECONDARY STUDY OBJECTIVES:

- Minimal pollutant removal, as noted above.

ADVANTAGES:

- Lower cost than ED basins or wet ponds.

DISADVANTAGES:

a. Human Risk, Public Safety and Potential Liability
   - Possible drownings during storm events

b. Environmental Risk and Implications
   - Minimal pollutant removal, so that contaminants are carried downstream to receiving bodies.

c. Other
   - Not applicable to stormwater quality control

COST INFORMATION (CAPITAL, OPERATION, MAINTENANCE, REPLACEMENT):

a. Capital costs
   - Lower than ED or wet ponds, due to smaller volume required for storage.

b. O&M Costs
   - Similar to ED basins.

c. Longevity
   - 20+ years

PROBABLE IMPLEMENTABILITY WITHIN SPRINGFIELD (SOCIAL, ECONOMIC, POLITICAL, AND CONSISTENCY WITH COMMUNITY VALUES):

a. Acceptability to Public, Stakeholders, Staff, Political Leadership
   - Does not meet water quality issues

b. Equitability to Impacted Persons
   - Land requirement and costs are less than other BMPs.

c. Amenity or Multi-Use Value
   - Possible recreation use

d. Fit with other Operations and Programs
   - Not effective with other BMPs

e. Relationship to Federal, State or Local Requirements

MAINTENANCE/MONITORING/ENFORCEMENT CONSIDERATIONS:

a. Reliability and Consistency over Time
   - Not effective as water quality control BMP

b. Routine and Non-routine Maintenance
   - Similar to ED basins

c. Sustainability of Maintenance or Program Management
   - Similar to ED basins

APPENDIX 8
FULBRIGHT SPRING WATER QUALITY DATA SUMMARY 1985-1993

Fullright Spring 1985 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.2	14.7	430.6	3.6	176.0	202.3	187.0	75.0		9.2	
MAXIMUM	7.7	20.0	497.0	17.7	202.0	242.0	217.0	87.0		65.0	
MINIMUM	6.6	9.0	354.0	0.1	135.0	161.0	147.0	59.0		0.0	
STANDARD DEVIATION	0.3	2.5	29.3	3.2	11.7	13.0	12.1	4.8		9.5	
85TH PERCENTILE	7.4	17.0	458.1	4.5	187.4	213.7	197.0	78.8		13.0	
COUNT	51.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0		50.0	

Fullright Spring 1986 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.4	15.0	442.6	5.0	178.5	206.5	188.0	75.0	#DIV/0!	7.3	252.0
MAXIMUM	7.8	28.0	487.0	83.0	199.0	238.0	204.0	81.7	0.0	24.0	324.0
MINIMUM	7.1	10.0	332.0	0.2	148.0	155.0	131.0	52.3	0.0	0.0	156.0
STANDARD DEVIATION	0.1	3.6	29.3	12.2	11.0	13.8	13.3	5.8	#DIV/0!	7.0	86.5
85TH PERCENTILE	7.5	18.0	468.0	4.3	188.0	217.4	199.4	79.5	#NUM!	16.6	309.6
COUNT	52.0	51.0	52.0	52.0	52.0	52.0	52.0	51.0	0.0	49.0	3.0

Fullright Spring 1987 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	15.1	456.0	3.1	181.0	211.9	194.0	78.2	#DIV/0!	3.4	189.1
MAXIMUM	8.0	20.0	532.0	14.3	202.0	288.0	217.0	87.0	0.0	26.0	304.0
MINIMUM	7.1	8.0	283.0	0.1	103.0	122.0	100.0	40.2	0.0	0.0	48.0
STANDARD DEVIATION	0.2	3.1	42.8	2.9	16.2	26.5	21.0	7.1	#DIV/0!	5.6	93.8
85TH PERCENTILE	7.5	18.0	490.5	5.7	193.0	234.7	209.0	83.6	#NUM!	7.5	278.8
COUNT	51.0	45.0	51.0	51.0	52.0	52.0	51.0	51.0	0.0	46.0	7.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
	7909.0	668.0	93.2				2.5	0.0			
	57000.0	4000.0	1400.0				4.3	0.1			
	100.0	0.0	0.0				0.0	0.0			
	10902.1	1049.4	217.4				1.0	0.0			
	13720.0	1000.0	130.0				3.5	0.0			
	50.0	50.0	50.0				51.0	51.0			

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
6.0	6261.3	1843.3	58.9	15.7	#DIV/0!	#DIV/0!	2.5	0.0	0.0	#DIV/0!	#DIV/0!
14.0	42000.0	32000.0	600.0	19.0	0.0	0.0	7.4	0.2	0.0	0.0	0.0
0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
7.2	8798.8	5152.2	121.4	4.9	#DIV/0!	#DIV/0!	1.6	0.0	#DIV/0!	#DIV/0!	#DIV/0!
11.0	12100.0	2000.0	115.0	18.7	#NUM!	#NUM!	4.3	0.1	0.0	#NUM!	#NUM!
3.0	47.0	52.0	46.0	3.0	0.0	0.0	51.0	51.0	1.0	0.0	0.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
1.8	3642.2	634.8	60.2	20.9	#DIV/0!	#DIV/0!	2.0	26.0	9.1	#DIV/0!	0.0
6.0	28000.0	6000.0	410.0	29.0	0.0	0.0	20.0	85.0	13.0	0.0	0.0
0.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0
2.0	4451.8	1104.4	76.2	5.6	#DIV/0!	#DIV/0!	2.7	13.1	4.4	#DIV/0!	0.0
2.0	6775.0	850.0	102.8	25.9	#NUM!	#NUM!	2.6	35.0	12.1	#NUM!	0.0
8.0	46.0	51.0	44.0	8.0	0.0	0.0	51.0	51.0	7.0	0.0	2.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
							0.0					
							0.0					
							0.0					
							0.0					
							0.0					
							51.0					

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
160.0	0	0	295.0	10.0	9.0	#DIV/0!	0.0	1870.0	0.0	0.0	10200.0	9.0
160.0	0	0	295.0	10.0	9.0	0.0	0.0	1870.0	0.0	0.0	10200.0	9.0
160.0	0	0	295.0	10.0	9.0	0.0	0.0	1870.0	0.0	0.0	10200.0	9.0
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
160.0	0	0	295.0	10.0	9.0	#NUM!	0.0	1870.0	0.0	0.0	10200.0	9.0
1.0	1	1	1.0	1.0	1.0	0.0	20.0	1.0	1.0	1.0	1.0	1.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
140.0	0	0	10.5	7.5	5.0	#DIV/0!	0.0	2700.0	0.0	2.5	13690.0	0.0
280.0	0	0	11.0	15.0	10.0	0.0	0.0	3200.0	0.0	5.0	15510.0	0.0
0.0	0	0	10.0	0.0	0.0	0.0	0.0	2200.0	0.0	0.0	11870.0	0.0
198.0	0	0	0.7	10.6	7.1	#DIV/0!	0.0	707.1	0.0	3.5	2573.9	0.0
238.0	0	0	10.9	12.8	8.5	#NUM!	0.0	3050.0	0.0	4.3	14964.0	0.0
2.0	2	2	2.0	2.0	2.0	0.0	7.0	2.0	2.0	2.0	2.0	2.0

Beryllium	Thallium	Tin

Beryllium	Thallium	Tin
#DIV/0!	#DIV/0!	#DIV/0!
0	0	0
0	0	0
#DIV/0!	#DIV/0!	#DIV/0!
#NUM!	#NUM!	#NUM!
0	0	0

Beryllium	Thallium	Tin
#DIV/0!	#DIV/0!	#DIV/0!
0	0	0
0	0	0
#DIV/0!	#DIV/0!	#DIV/0!
#NUM!	#NUM!	#NUM!
0	0	0

Fulbright Spring 1988 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	15.2	469.1	2.5	180.9	203.1	192.2	76.9	#DIV/0!	0.8	267.7
MAXIMUM	7.5	21.0	595.0	7.1	201.0	221.0	209.0	83.6	0.0	3.0	358.0
MINIMUM	6.9	10.0	380.0	0.0	134.0	140.0	142.0	56.8	0.0	0.0	218.0
STANDARD DEVIATION	0.1	2.8	38.8	1.8	13.5	14.7	13.1	5.3	#DIV/0!	1.2	47.8
85TH PERCENTILE	7.4	18.0	499.9	4.9	192.0	213.9	204.0	81.5	#NUM!	2.0	295.0
COUNT	35.0	33.0	35.0	35.0	35.0	35.0	35.0	35.0	0.0	9.0	6.0

Fulbright Spring 1989 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	16.1	482.0	3.2	182.5	209.6	197.7	78.6	#DIV/0!	7.0	222.0
MAXIMUM	7.6	19.0	536.0	17.3	209.0	246.0	236.0	94.6	0.0	7.0	222.0
MINIMUM	7.1	11.0	350.0	0.6	146.0	163.0	153.0	61.0	0.0	7.0	222.0
STANDARD DEVIATION	0.1	2.7	38.6	3.7	15.6	19.2	18.2	7.5	#DIV/0!	#DIV/0!	#DIV/0!
85TH PERCENTILE	7.4	18.0	509.4	4.3	194.7	230.0	220.0	87.3	#NUM!	7.0	222.0
COUNT	32.0	31.0	32.0	32.0	32.0	32.0	32.0	32.0	0.0	1.0	1.0

Fulbright Spring 1990 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.4	16.6	449.7	3.1	178.8	205.9	193.5	77.5	#DIV/0!	12.0	250.0
MAXIMUM	7.7	20.0	515.0	20.0	209.0	236.0	212.0	84.9	0.0	24.0	250.0
MINIMUM	7.1	11.0	385.0	0.5	126.0	183.0	165.0	66.1	0.0	0.0	250.0
STANDARD DEVIATION	0.1	2.1	33.7	3.5	15.2	12.0	9.8	4.0	#DIV/0!	17.0	#DIV/0!
85TH PERCENTILE	7.5	19.0	486.7	5.0	194.8	217.6	204.0	81.7	#NUM!	20.4	250.0
COUNT	45.0	40.0	43.0	44.0	45.0	44.0	45.0	45.0	0.0	2.0	1.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
3.7	1870.8	164.0	15.4	19.1	#DIV/0!	#DIV/0!	2.1	24.4	12.9	18.5	0.0
8.0	24000.0	1000.0	60.0	27.0	0.0	0.0	7.2	90.0	15.4	60.0	0.0
2.0	45.0	5.0	0.0	12.0	0.0	0.0	0.1	1.0	8.4	0.0	0.0
2.3	5345.6	276.4	14.6	5.5	#DIV/0!	#DIV/0!	1.4	15.3	2.5	27.1	0.0
5.0	1190.0	200.0	25.5	24.3	#NUM!	#NUM!	2.3	34.0	14.6	56.6	0.0
6.0	20.0	20.0	18.0	7.0	0.0	0.0	35.0	34.0	7.0	8.0	8.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
2.0	4971.0	565.4	49.9	26.5	#DIV/0!	#DIV/0!	1.7	34.0	10.8	60.0	0.0
2.0	10800.0	4000.0	220.0	30.0	0.0	0.0	3.4	111.0	11.0	140.0	0.0
2.0	1570.0	0.0	0.0	23.0	0.0	0.0	1.0	5.7	10.6	0.0	0.0
#DIV/0!	2582.0	1059.6	63.5	4.9	#DIV/0!	#DIV/0!	0.5	24.9	0.3	72.1	0.0
2.0	6299.0	582.0	100.0	29.0	#NUM!	#NUM!	2.2	51.2	10.9	110.0	0.0
1.0	10.0	13.0	12.0	2.0	0.0	0.0	32.0	27.0	2.0	3.0	3.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
10.0	#DIV/0!	#DIV/0!	#DIV/0!	18.2	#DIV/0!	#DIV/0!	2.0	34.4	9.5	32.0	0.0
10.0	0.0	0.0	0.0	24.0	0.0	0.0	2.6	72.0	10.0	140.0	0.0
10.0	0.0	0.0	0.0	12.9	0.0	0.0	1.4	0.0	8.8	0.0	0.0
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	5.1	#DIV/0!	#DIV/0!	0.3	17.4	0.5	55.1	0.0
10.0	#NUM!	#NUM!	#NUM!	23.0	#NUM!	#NUM!	2.3	51.4	9.8	65.0	0.0
1.0	0.0	0.0	0.0	5.0	0.0	0.0	40.0	32.0	5.0	6.0	6.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
83.8	80.625	0	29.5	37.3	0.0	1.6	0.7	1416.3	0.0	0.0	8420.0	1.9
480.0	530	0	89.0	80.0	0.0	8.0	4.0	1900.0	0.0	0.0	10480.0	15.0
0.0	0	0	0.0	0.0	0.0	0.0	0.0	1020.0	0.0	0.0	6100.0	0.0
173.4	185.9807	0	39.5	32.5	0.0	3.6	1.6	304.3	0.0	0.0	1560.8	5.3
180.5	109.25	0	79.9	63.7	0.0	3.2	1.0	1689.0	0.0	0.0	9605.0	0.0
8.0	8	8	8.0	8.0	8.0	5.0	6.0	8.0	8.0	8.0	8.0	8.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
0.0	0	0	46.3	89.3	0.0	25.0	#DIV/0!	1350.0	0.0	0.0	6106.7	0.0
0.0	0	0	75.0	112.0	0.0	31.0	0.0	1550.0	0.0	0.0	7750.0	0.0
0.0	0	0	0.0	62.0	0.0	21.0	0.0	1240.0	0.0	0.0	3380.0	0.0
0.0	0	0	40.5	25.3	0.0	5.3	#DIV/0!	173.5	0.0	0.0	2377.9	0.0
0.0	0	0	71.7	106.6	0.0	28.6	#NUM!	1463.0	0.0	0.0	7582.0	0.0
3.0	3	3	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
0.0	0	0	8.8	53.7	0.0	28.5	0.0	1109.5	0.0	0.0	9058.5	12.2
0.0	0	0	42.0	148.0	0.0	69.0	0.0	1591.0	0.0	0.0	11600.0	73.0
0.0	0	0	0.0	9.0	0.0	7.0	0.0	808.0	0.0	0.0	6520.0	0.0
0.0	0	0	16.8	49.2	0.0	21.6	#DIV/0!	319.9	0.0	0.0	1864.2	29.8
0.0	0	0	18.8	80.5	0.0	42.0	0.0	1459.8	0.0	0.0	10685.0	18.3
6.0	6	6	6.0	6.0	6.0	6.0	1.0	6.0	6.0	2.0	6.0	6.0

Beryllium Thallium Tin

Beryllium Thallium Tin

Beryllium Thallium Tin

Fulbright Spring 1991 Values 11/5/91

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	16.6	470.7	2.3	186.8	214.9	201.1	80.6	3.4	2.0	300.7
MAXIMUM	8.0	23.0	545.0	14.5	206.2	246.4	228.6	91.6	8.7	6.0	338.0
MINIMUM	7.0	12.6	370.0	0.3	160.4	182.2	175.4	70.3	0.6	0.0	246.0
STANDARD DEVIATION	0.2	2.5	39.8	2.7	12.7	16.4	13.2	5.3	1.6	3.5	48.4
85TH PERCENTILE	7.3	18.0	516.2	3.5	200.0	229.1	212.4	85.1	4.5	4.2	332.0
COUNT	38.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	3.0	3.0

Fulbright Spring 1992 Values 11/5/91

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	16.5	477.3	2.0	197.0	223.2	212.1	85.0	2.7	1.5	313.0
MAXIMUM	7.8	24.0	511.0	7.2	225.4	244.6	243.8	97.7	6.1	3.0	380.0
MINIMUM	6.9	11.2	379.0	0.4	172.8	196.8	178.4	71.5	0.2	0.0	274.0
STANDARD DEVIATION	0.2	3.3	30.3	1.9	13.1	12.3	13.5	5.4	1.7	2.1	58.3
85TH PERCENTILE	7.5	19.6	505.6	3.6	209.0	237.8	223.9	89.8	5.3	2.6	351.5
COUNT	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	2.0	3.0

Fulbright Spring 1993 Values

	pH	Temp.	Cond.	Turbidity	Alkalinity	T. Hard.	Ca Hard	Calcium	Mg	Color	TDS
AVERAGE	7.3	15.3	418.6	2.7	193.7	215.8	205.7	82.4	2.5	0.0	178.5
MAXIMUM	7.6	19.5	554.0	13.0	212.2	237.6	225.6	90.4	8.6	0.0	254.0
MINIMUM	7.0	11.5	279.0	0.1	173.6	190.6	182.0	72.9	0.4	0.0	50.0
STANDARD DEVIATION	0.2	2.4	53.3	2.3	9.6	11.0	10.8	4.3	1.6	0.0	95.4
85TH PERCENTILE	7.5	18.3	463.2	4.3	203.1	227.3	217.4	87.1	3.8	0.0	251.3
COUNT	49.0	49.0	47.0	49.0	49.0	49.0	49.0	49.0	49.0	4.0	4.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
2.3	8992.9	1085.0	99.4	24.9	0.2	0.1	1.9	ND	9.0	25.3	0.0
6.0	96000.0	12000.0	1300.0	49.0	0.3	0.1	4.0	0.0	11.1	31.0	0.0
0.0	800.0	0.0	0.0	6.1	0.1	0.1	1.1	0.0	6.8	15.0	0.0
3.2	18515.0	2607.0	267.3	8.1	0.2	#DIV/0!	0.6	#DIV/0!	0.9	7.7	0.0
4.5	10225.0	1450.0	58.4	30.5	0.3	0.1	2.1	#NUM!	10.2	31.0	0.0
3.0	26.0	36.0	37.0	39.0	2.0	1.0	39.0	0.0	39.0	6.0	4.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
2.0	1148316.8	1319.3	117.4	23.5	#DIV/0!	0.1	2.1	#DIV/0!	9.0	34.7	0.0
5.0	15000000.0	9400.0	1210.0	30.4	0.0	0.1	2.8	0.0	11.3	97.0	0.0
0.0	920.0	0.0	0.0	16.2	0.0	0.1	0.7	0.0	1.1	20.0	0.0
2.6	3353471.4	2185.0	229.5	3.4	#DIV/0!	#DIV/0!	0.5	#DIV/0!	1.5	23.6	0.0
3.8	886000.0	2740.0	200.0	27.5	#NUM!	0.1	2.6	#NUM!	9.6	44.0	0.0
3.0	34.0	43.0	43.0	32.0	0.0	1.0	32.0	0.0	32.0	10.0	11.0

TSS	Atypical Bacteria	Total Coliform	Fecal Coliform	Chloride	Nitrite-N	Bromide	Nitrate-N	Ortho-Phosphate	Sulfate	Aluminum	Arsenic
5.3	15667.1	1044.1	120.1	19.3	0.1	0.1	2.3	#DIV/0!	8.8	66.1	0.2
8.0	86000.0	15000.0	600.0	30.5	0.1	0.3	2.8	0.0	12.8	152.0	0.9
2.0	100.0	0.0	0.0	6.1	0.1	0.1	1.5	0.0	7.1	13.0	0.0
2.8	22108.6	2703.9	177.9	4.8	#DIV/0!	0.1	0.3	#DIV/0!	1.0	44.5	0.4
7.6	27350.0	1200.0	400.0	22.8	0.1	0.1	2.6	#NUM!	9.4	100.4	0.7
4.0	34.0	49.0	47.0	49.0	1.0	9.0	49.0	0.0	49.0	9.0	8.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
382.5	0.0	4.8	20.5	44.8	0.0	30.2	0.0	1388.5	0.0	0.0	11536.3	2.5
490.0	0.0	15.0	46.0	79.0	0.0	54.0	0.0	1744.0	0.0	0.0	16124.0	5.0
210.0	0.0	0.0	0.0	16.0	0.0	5.0	0.0	995.0	0.0	0.0	8550.0	0.0
120.4	0.0	6.9	21.8	27.5	0.0	18.5	#DIV/0!	254.1	0.0	0.0	2494.9	3.5
458.5	0.0	11.4	39.3	74.5	0.0	46.5	0.0	1704.1	0.0	0.0	12763.4	4.3
4.0	4.0	5.0	4.0	6.0	4.0	6.0	1.0	8.0	4.0	2.0	7.0	2.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
379.7	0	0	11.2	44.5	0.0	1.7	#DIV/0!	1625.1	0.0	0.0	11023.8	17.7
769.0	0	0	19.0	56.0	0.0	5.0	0.0	2294.0	0.0	0.0	14734.0	29.0
92.0	0	0	0.0	33.0	0.0	0.0	0.0	1154.0	0.0	0.0	6310.0	0.0
216.3	0	0	8.0	8.9	0.0	2.9	#DIV/0!	407.1	0.0	0.0	2343.7	15.5
575.4	0	0	17.7	51.5	0.0	3.5	#NUM!	2097.0	0.0	0.0	12902.0	27.5
10.0	11.0	11.0	10.0	6.0	10.0	3.0	0.0	11.0	10.0	3.0	11.0	3.0

Barium	Cadmium	Chromium	Copper	Iron	Lead	Mn	Mercury	Potassium	Selenium	Silver	Sodium	Zinc
202.6	13.82857	0.855556	12.4	79.1	0.4	27.8	1.1	1477.4	0.2	0.8	7942.3	11.0
320.0	96.7	7	24.0	206.0	2.5	53.0	1.1	2460.0	1.0	4.0	9678.0	25.0
53.0	0	0	0.0	23.0	0.0	0.0	1.1	803.0	0.0	0.0	4624.0	2.0
111.4	36.54288	2.315767	7.5	62.4	0.8	20.0	#DIV/0!	571.4	0.4	1.8	1666.1	10.7
310.4	9.76	0.56	18.9	110.6	0.5	46.7	1.1	2078.6	0.7	1.6	9510.4	22.0
5.0	7	9	8.0	7.0	9.0	8.0	1.0	9.0	9.0	5.0	9.0	5.0

Beryllium	Thallium	Tin
0	0	0
0	0	0
0	0	0
0	#DIV/0!	0
0	0	0
2	1	2

APPENDIX 9
1990 SAMPLING FOR ORGANICS
VALLEY MILLS DAM AND FULBRIGHT SPRING

Enseco
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Priority Pollutant Volatile Organics

Method 524

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 06 JUN 90

Parameter	Result	Units	Reporting Limit
Vinyl chloride	ND	ug/L	2.0
Methylene chloride	ND	ug/L	5.0
1,1-Dichloroethene	ND	ug/L	1.0
1,2-Dichloroethene (cis/trans)	ND	ug/L	1.0
Chloroform	ND	ug/L	1.0
1,2,3-Trichlorobenzene	ND	ug/L	1.0
1,2,4-Trichlorobenzene	ND	ug/L	1.0
1,1,1-Trichloroethane	ND	ug/L	1.0
Carbon tetrachloride	ND	ug/L	1.0
Bromodichloromethane	ND	ug/L	1.0
1,2-Dichloropropane	ND	ug/L	1.0
Trichloroethene	ND	ug/L	1.0
Dibromochloromethane	ND	ug/L	1.0
1,1,2-Trichloroethane	ND	ug/L	1.0
Benzene	ND	ug/L	1.0
Bromoform	ND	ug/L	1.0
Tetrachloroethene	ND	ug/L	1.0
Toluene	ND	ug/L	1.0
Chlorobenzene	ND	ug/L	1.0
Ethylbenzene	ND	ug/L	1.0
Xylenes (total)	ND	ug/L	1.0
1,4-Dichlorobenzene	ND	ug/L	1.0
1,3-Dichlorobenzene	ND	ug/L	1.0
DBCP (1,2-Dibromo-3-chloropropane)	ND	ug/L	1.0
EDB (1,2-Dibromoethane)	ND	ug/L	1.0
Toluene-d8	101	%	--
4-Bromofluorobenzene	107	%	--
1,2-Dichloroethane-d4	80	%	--

ND = Not detected
NA = Not applicable

Reported By: Terry Riddle Approved By: Jeff Lowry

Enseco
A CORNING Company

Priority Pollutant Volatile Organics

Method 524

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 06 JUN 90

Parameter	Result	Units	Reporting Limit
Vinyl chloride	ND	ug/L	2.0
Methylene chloride	ND	ug/L	5.0
1,1-Dichloroethene	ND	ug/L	1.0
1,2-Dichloroethene (cis/trans)	ND	ug/L	1.0
Chloroform	ND	ug/L	1.0
1,2,3-Trichlorobenzene	ND	ug/L	1.0
1,2,4-Trichlorobenzene	ND	ug/L	1.0
1,1,1-Trichloroethane	ND	ug/L	1.0
Carbon tetrachloride	ND	ug/L	1.0
Bromodichloromethane	ND	ug/L	1.0
1,2-Dichloropropane	ND	ug/L	1.0
Trichloroethene	ND	ug/L	1.0
Dibromochloromethane	ND	ug/L	1.0
1,1,2-Trichloroethane	ND	ug/L	1.0
Benzene	ND	ug/L	1.0
Bromoform	ND	ug/L	1.0
Tetrachloroethene	ND	ug/L	1.0
Toluene	ND	ug/L	1.0
Chlorobenzene	ND	ug/L	1.0
Ethylbenzene	ND	ug/L	1.0
Xylenes (total)	ND	ug/L	1.0
1,4-Dichlorobenzene	ND	ug/L	1.0
1,3-Dichlorobenzene	ND	ug/L	1.0
DBCP (1,2-Dibromo-3-chloropropane)	ND	ug/L	1.0
EDB (1,2-Dibromoethane)	ND	ug/L	1.0
Toluene-d8	106	%	--
4-Bromofluorobenzene	99	%	--
1,2-Dichloroethane-d4	92	%	--

ND = Not detected
NA = Not applicable

Reported By: Terry Riddle Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics

Method 8270

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 16 JUN 90 Analyzed: 29 JUN 90

Parameter	Result	Units	Reporting Limit
Acenaphthene	ND	ug/L	10
Acenaphthylene	ND	ug/L	10
Acetophenone	ND	ug/L	10
2-Acetylaminofluorene	ND	ug/L	10
4-Aminobiphenyl	ND	ug/L	10
Aniline	ND	ug/L	10
Anthracene	ND	ug/L	10
Aramite	ND	ug/L	10
Benzo(a)anthracene	ND	ug/L	10
Benzo(b)fluoranthene	ND	ug/L	10
Benzo(k)fluoranthene	ND	ug/L	10
Benzo(g,h,i)perylene	ND	ug/L	10
Benzo(a)pyrene	ND	ug/L	10
bis(2-Chloroethoxy)-methane	ND	ug/L	10
Benzyl alcohol	ND	ug/L	20
bis(2-Chloroethyl) ether	ND	ug/L	10
bis(2-Chloroisopropyl)-ether	ND	ug/L	10
bis(2-Ethylhexyl) phthalate	ND	ug/L	10
4-Bromophenyl phenyl ether	ND	ug/L	10
Butyl benzyl phthalate	ND	ug/L	10
2-sec-Butyl-4,6-dinitro-phenol	ND	ug/L	10
4-Chloroaniline	ND	ug/L	20
4-Chloro-3-methylphenol	ND	ug/L	20
2-Chloronaphthalene	ND	ug/L	10
2-Chlorophenol	ND	ug/L	10
4-Chlorophenyl phenyl ether	ND	ug/L	10
o-Cresol	ND	ug/L	10
m & p-Cresol(s)	ND	ug/L	10
Chrysene	ND	ug/L	10
Dibenz(a,h)anthracene	ND	ug/L	10
Dibenzofuran	ND	ug/L	10
Di-n-butyl phthalate	ND	ug/L	10
1,2-Dichlorobenzene	ND	ug/L	10
1,3-Dichlorobenzene	ND	ug/L	10
1,4-Dichlorobenzene	ND	ug/L	10

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Scott Frencis Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 16 JUN 90 Analyzed: 29 JUN 90

Parameter	Result	Units	Reporting Limit
3,3'-Dichlorobenzidine	ND	ug/L	20
2,4-Dichlorophenol	ND	ug/L	10
2,6-Dichlorophenol	ND	ug/L	10
Diethyl phthalate	ND	ug/L	10
p-Dimethylaminoazobenzene	ND	ug/L	10
7,12-Dimethylbenz(a)-anthracene	ND	ug/L	10
3,3'-Dimethylbenzidine	ND	ug/L	10
a,a-Dimethylphenethylamine	ND	ug/L	10
2,4-Dimethylphenol	ND	ug/L	10
Dimethyl phthalate	ND	ug/L	10
1,3-Dinitrobenzene	ND	ug/L	10
4,6-Dinitro-o-cresol	ND	ug/L	50
2,4-Dinitrophenol	ND	ug/L	50
2,4-Dinitrotoluene	ND	ug/L	10
2,6-Dinitrotoluene	ND	ug/L	10
Di-n-octyl phthalate	ND	ug/L	10
Diphenylamine	ND	ug/L	10
Ethyl methacrylate	ND	ug/L	10
Ethyl methanesulfonate	ND	ug/L	10
Fluoranthene	ND	ug/L	10
Fluorene	ND	ug/L	10
Hexachlorobenzene	ND	ug/L	10
Hexachlorobutadiene	ND	ug/L	10
Hexachlorocyclopentadiene	ND	ug/L	10
Hexachloroethane	ND	ug/L	10
Hexachlorophene	ND	ug/L	--
Hexachloropropene	ND	ug/L	20
Indeno(1,2,3-cd)pyrene	ND	ug/L	10
Isophorone	ND	ug/L	10
Isosafrole	ND	ug/L	20
Methapyrilene	ND	ug/L	10
3-Methylcholanthrene	ND	ug/L	20
Methyl methacrylate	ND	ug/L	10
Methyl methanesulfonate	ND	ug/L	10
2-Methylnaphthalene	ND	ug/L	10
Naphthalene	ND	ug/L	10
1,4-Naphthoquinone	ND	ug/L	10
1-Naphthylamine	ND	ug/L	10
2-Naphthylamine	ND	ug/L	10

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Scott Frencis Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 16 JUN 90 Analyzed: 29 JUN 90

Parameter	Result	Units	Reporting Limit
2-Nitroaniline	ND	ug/L	50
3-Nitroaniline	ND	ug/L	50
4-Nitroaniline	ND	ug/L	50
Nitrobenzene	ND	ug/L	10
2-Nitrophenol	ND	ug/L	10
4-Nitrophenol	ND	ug/L	50
4-Nitroquinoline-1-oxide	ND	ug/L	--
N-Nitroso-di-n-butylamine	ND	ug/L	10
N-Nitrosodiethylamine	ND	ug/L	10
N-Nitrosodimethylamine	ND	ug/L	10
N-Nitrosodiphenylamine	ND	ug/L	10
N-Nitroso-di-n-propylamine	ND	ug/L	10
N-Nitrosomethylethylamine	ND	ug/L	10
N-Nitrosomorpholine	ND	ug/L	10
N-Nitrosopiperidine	ND	ug/L	10
N-Nitrosopyrrolidine	ND	ug/L	10
5-Nitro-o-toluidine	ND	ug/L	10
Pentachlorobenzene	ND	ug/L	10
Pentachloroethane	ND	ug/L	10
Pentachloronitrobenzene	ND	ug/L	50
Pentachlorophenol	ND	ug/L	50
Phenacetin	ND	ug/L	10
Phenanthrene	ND	ug/L	10
Phenol	ND	ug/L	10
p-Phenylenediamine	ND	ug/L	--
2-Picoline	ND	ug/L	10
Pronamide	ND	ug/L	20
Pyrene	ND	ug/L	10
Pyridine	ND	ug/L	10
Safrole	ND	ug/L	10
1,2,4,5-Tetrachlorobenzene	ND	ug/L	10
2,3,4,6-Tetrachlorophenol	ND	ug/L	20
o-Toluidine	ND	ug/L	10
1,2,4-Trichlorobenzene	ND	ug/L	10
2,4,5-Trichlorophenol	ND	ug/L	50
0,0,0-Triethylphosphorothioate	ND	ug/L	50
2,4,6-Trichlorophenol	ND	ug/L	10
Ethyl parathion	ND	ug/L	50

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Scott Frencis Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 16 JUN 90 Analyzed: 29 JUN 90

Parameter	Result	Units	Reporting Limit
Phorate (Thimet)	ND	ug/L	100
Sulfotepp	ND	ug/L	50
Thionazin	ND	ug/L	50
sym-Trinitrobenzene	ND	ug/L	10
Dimethoate	ND	ug/L	--
Disulfoton	ND	ug/L	50
Famphur	ND	ug/L	100
Methyl parathion	ND	ug/L	50
Nitrobenzene-d5	55	%	--
2-Fluorobiphenyl	56	%	--
Terphenyl-d14	72	%	--
Phenol-d5	60	%	--
2-Fluorophenol	57	%	--
2,4,6-Tribromophenol	70	%	--

ND = Not detected
NA = Not applicable

Reported By: Scott Frencis Approved By: Jeff Lowry

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TENTATIVELY IDENTIFIED COMPOUNDS

FOR

CITY UTILITIES OF SPRINGFIELD

SAMPLE NUMBER 009814-0001

Compound Name	Fraction	Confidence Level	Estimated Concentration ug/L
None Detected	BNA		

NOTES:

Confidence Levels

Level 3 - Confirmed Identification
Level 2 - Confident Identification
Level 1 - Tentative Identification

Qualifiers

B - Blank Contaminant
I - Isomer
C - Class

Please refer to the discussion for further details.

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Appendix IX Semivolatile Organics

Method 8270

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 13 JUN 90

Parameter	Result	Units	Reporting Limit
Acenaphthene	ND	ug/L	10
Acenaphthylene	ND	ug/L	10
Acetophenone	ND	ug/L	10
2-Acetylaminofluorene	ND	ug/L	10
4-Aminobiphenyl	ND	ug/L	10
Aniline	ND	ug/L	10
Anthracene	ND	ug/L	10
Aramite	ND	ug/L	10
Benzo(a)anthracene	ND	ug/L	10
Benzo(b)fluoranthene	ND	ug/L	10
Benzo(k)fluoranthene	ND	ug/L	10
Benzo(g,h,i)perylene	ND	ug/L	10
Benzo(a)pyrene	ND	ug/L	10
Benzyl alcohol	ND	ug/L	20
bis(2-Chloroethoxy)-methane	ND	ug/L	10
bis(2-Chloroethyl) ether	ND	ug/L	10
bis(2-Chloroisopropyl)-ether	ND	ug/L	10
bis(2-Ethylhexyl) phthalate	10	ug/L	10 ☆
4-Bromophenyl phenyl ether	ND	ug/L	10
Butyl benzyl phthalate	ND	ug/L	10
2-sec-Butyl-4,6-dinitro-phenol	ND	ug/L	10
4-Chloroaniline	ND	ug/L	20
4-Chloro-3-methylphenol	ND	ug/L	20
2-Chloronaphthalene	ND	ug/L	10
2-Chlorophenol	ND	ug/L	10
4-Chlorophenyl phenyl ether	ND	ug/L	10
o-Cresol	ND	ug/L	10
m & p-Cresol(s)	ND	ug/L	10
Chrysene	ND	ug/L	10
Dibenz(a,h)anthracene	ND	ug/L	10
Dibenzofuran	ND	ug/L	10
Di-n-butyl phthalate	ND	ug/L	10
1,2-Dichlorobenzene	ND	ug/L	10
1,3-Dichlorobenzene	ND	ug/L	10
1,4-Dichlorobenzene	ND	ug/L	10

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Lisa Traut Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 13 JUN 90

Parameter	Result	Units	Reporting Limit
3,3'-Dichlorobenzidine	ND	ug/L	20
2,4-Dichlorophenol	ND	ug/L	10
2,6-Dichlorophenol	ND	ug/L	10
Diethyl phthalate	ND	ug/L	10
p-Dimethylaminoazobenzene	ND	ug/L	10
7,12-Dimethylbenz(a)-anthracene	ND	ug/L	10
3,3'-Dimethylbenzidine	ND	ug/L	10
a,a-Dimethylphenethylamine	ND	ug/L	10
2,4-Dimethylphenol	ND	ug/L	10
Dimethyl phthalate	ND	ug/L	10
1,3-Dinitrobenzene	ND	ug/L	10
4,6-Dinitro-o-cresol	ND	ug/L	50
2,4-Dinitrophenol	ND	ug/L	50
2,4-Dinitrotoluene	ND	ug/L	10
2,6-Dinitrotoluene	ND	ug/L	10
Di-n-octyl phthalate	ND	ug/L	10
Diphenylamine	ND	ug/L	10
Ethyl methacrylate	ND	ug/L	10
Ethyl methanesulfonate	ND	ug/L	10
Fluoranthene	ND	ug/L	10
Fluorene	ND	ug/L	10
Hexachlorobenzene	ND	ug/L	10
Hexachlorobutadiene	ND	ug/L	10
Hexachlorocyclopentadiene	ND	ug/L	10
Hexachloroethane	ND	ug/L	10
Hexachlorophene	ND	ug/L	--
Hexachloropropene	ND	ug/L	20
Indeno(1,2,3-cd)pyrene	ND	ug/L	10
Isophorone	ND	ug/L	10
Isosafrole	ND	ug/L	20
Methapyrilene	ND	ug/L	10
3-Methylcholanthrene	ND	ug/L	20
Methyl methacrylate	ND	ug/L	10
Methyl methanesulfonate	ND	ug/L	10
2-Methylnaphthalene	ND	ug/L	10
Naphthalene	ND	ug/L	10
1,4-Naphthoquinone	ND	ug/L	10
1-Naphthylamine	ND	ug/L	10
2-Naphthylamine	ND	ug/L	10

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Lisa Traut Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 13 JUN 90

Parameter	Result	Units	Reporting Limit
2-Nitroaniline	ND	ug/L	50
3-Nitroaniline	ND	ug/L	50
4-Nitroaniline	ND	ug/L	50
Nitrobenzene	ND	ug/L	10
2-Nitrophenol	ND	ug/L	10
4-Nitrophenol	ND	ug/L	50
4-Nitroquinoline-1-oxide	ND	ug/L	--
N-Nitroso-di-n-butylamine	ND	ug/L	10
N-Nitrosodiethylamine	ND	ug/L	10
N-Nitrosodimethylamine	ND	ug/L	10
N-Nitrosodiphenylamine	ND	ug/L	10
N-Nitroso-di-n-propylamine	ND	ug/L	10
N-Nitrosomethylethylamine	ND	ug/L	10
N-Nitrosomorpholine	ND	ug/L	10
N-Nitrosopiperidine	ND	ug/L	10
N-Nitrosopyrrolidine	ND	ug/L	10
5-Nitro-o-toluidine	ND	ug/L	10
Pentachlorobenzene	ND	ug/L	10
Pentachloroethane	ND	ug/L	10
Pentachloronitrobenzene	ND	ug/L	50
Pentachlorophenol	ND	ug/L	50
Phenacetin	ND	ug/L	10
Phenanthrene	ND	ug/L	10
Phenol	ND	ug/L	10
p-Phenylenediamine	ND	ug/L	--
2-Picoline	ND	ug/L	10
Pronamide	ND	ug/L	20
Pyrene	ND	ug/L	10
Pyridine	ND	ug/L	10
Safrole	ND	ug/L	10
1,2,4,5-Tetrachlorobenzene	ND	ug/L	10
2,3,4,6-Tetrachlorophenol	ND	ug/L	20
o-Toluidine	ND	ug/L	10
1,2,4-Trichlorobenzene	ND	ug/L	10
2,4,5-Trichlorophenol	ND	ug/L	50
O,O,O-Triethylphosphorothioate	ND	ug/L	50
2,4,6-Trichlorophenol	ND	ug/L	10
Ethyl parathion	ND	ug/L	50

(continued on following page)

ND = Not detected
NA = Not applicable

Reported By: Lisa Traut Approved By: Jeff Lowry

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Appendix IX Semivolatile Organics (CONT.)

Method 8270

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 06 JUN 90 Analyzed: 13 JUN 90

Parameter	Result	Units	Reporting Limit
Phorate (Thimet)	ND	ug/L	100
Sulfotepp	ND	ug/L	50
Thionazin	ND	ug/L	50
sym-Trinitrobenzene	ND	ug/L	10
Dimethoate	ND	ug/L	--
Disulfoton	ND	ug/L	50
Famphur	ND	ug/L	100
Methyl parathion	ND	ug/L	50
Nitrobenzene-d5	69	%	--
2-Fluorobiphenyl	59	%	--
Terphenyl-d14	73	%	--
Phenol-d5	64	%	--
2-Fluorophenol	63	%	--
2,4,6-Tribromophenol	55	%	--

ND = Not detected
NA = Not applicable

Reported By: Lisa Traut Approved By: Jeff Lowry

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TENTATIVELY IDENTIFIED COMPOUNDS

FOR

CITY UTILITIES OF SPRINGFIELD

SAMPLE NUMBER 009814-0002

Compound Name	Fraction	Confidence Level	Estimated Concentration ug/L
Oxygenated Hydrocarbon	BNA	1C	16

NOTES:

Confidence Levels

Level 3 - Confirmed Identification
Level 2 - Confident Identification
Level 1 - Tentative Identification

Qualifiers

B - Blank Contaminant
I - Isomer
C - Class

Please refer to the discussion for further details.

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2,3,7,8-TCDD

HIGH RESOLUTION

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 053102-0001-SA Enseco ID: 151087
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 04 JUN 90 Prepared: 13 JUN 90 Analyzed: 22 JUN 90

Sample Amount 0.987L
Column Type DB-5

Parameter	Result	Units	Detection Limit	Data Qualifiers
Dioxins				
2,3,7,8-TCDD	ND	pg/L	2.6	
	% Recovery			
13C-2,3,7,8-TCDD	97			

ND = Not detected
NA = Not applicable

Reported By: Martha Maier Approved By: Mike Filigenzi

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2,3,7,8-TCDD

HIGH RESOLUTION

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 053102-0002-SA Enseco ID: 151088
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 04 JUN 90 Prepared: 13 JUN 90 Analyzed: 22 JUN 90

Sample Amount 0.986L
Column Type DB-5

Parameter	Result	Units	Detection Limit	Data Qualifiers
Dioxins				
2,3,7,8-TCDD	ND	pg/L	3.1	
	% Recovery			
13C-2,3,7,8-TCDD	98			

ND = Not detected
NA = Not applicable

Reported By: Martha Maier Approved By: Mike Filigenzi

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Appendix IX Organochlorine Pesticides/PCBs

Method 8080

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 04 JUN 90 Analyzed: 15 JUN 90

Parameter	Result	Units	Reporting Limit
Aldrin	ND	ug/L	0.050
Aroclor 1016	ND	ug/L	0.50
Aroclor 1221	ND	ug/L	0.50
Aroclor 1232	ND	ug/L	0.50
Aroclor 1242	ND	ug/L	0.50
Aroclor 1248	ND	ug/L	0.50
Aroclor 1254	ND	ug/L	1.0
Aroclor 1260	ND	ug/L	1.0
alpha-BHC	ND	ug/L	0.050
beta-BHC	ND	ug/L	0.050
delta-BHC	ND	ug/L	0.050
gamma-BHC (Lindane)	ND	ug/L	0.050
Chlordane	ND	ug/L	0.50
Chlorobenzilate	ND	ug/L	0.50
4,4'-DDD	ND	ug/L	0.10
4,4'-DDE	ND	ug/L	0.10
4,4'-DDT	ND	ug/L	0.10
Diallate	ND	ug/L	1.5
Dieldrin	ND	ug/L	0.10
Endosulfan I	ND	ug/L	0.050
Endosulfan II	ND	ug/L	0.10
Endosulfan sulfate	ND	ug/L	0.10
Endrin	ND	ug/L	0.10
Endrin aldehyde	ND	ug/L	0.10
Heptachlor	ND	ug/L	0.050
Heptachlor epoxide	ND	ug/L	0.050
Isodrin	ND	ug/L	0.050
Kepone	ND	ug/L	0.10
Methoxychlor	ND	ug/L	0.50
Toxaphene	ND	ug/L	1.0
Dibutyl chlorendate	68	%	--

ND = Not detected
NA = Not applicable

Reported By: William Sullivan Approved By: Greg Gustina

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Appendix IX Organochlorine Pesticides/PCBs

Method 8080

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 04 JUN 90 Analyzed: 15 JUN 90

Parameter	Result	Units	Reporting Limit
Aldrin	ND	ug/L	0.050
Aroclor 1016	ND	ug/L	0.50
Aroclor 1221	ND	ug/L	0.50
Aroclor 1232	ND	ug/L	0.50
Aroclor 1242	ND	ug/L	0.50
Aroclor 1248	ND	ug/L	0.50
Aroclor 1254	ND	ug/L	1.0
Aroclor 1260	ND	ug/L	1.0
alpha-BHC	ND	ug/L	0.050
beta-BHC	ND	ug/L	0.050
delta-BHC	ND	ug/L	0.050
gamma-BHC (Lindane)	ND	ug/L	0.050
Chlordane	ND	ug/L	0.50
Chlorobenzilate	ND	ug/L	0.50
4,4'-DDD	ND	ug/L	0.10
4,4'-DDE	ND	ug/L	0.10
4,4'-DDT	ND	ug/L	0.10
Diallate	ND	ug/L	1.5
Dieldrin	ND	ug/L	0.10
Endosulfan I	ND	ug/L	0.050
Endosulfan II	ND	ug/L	0.10
Endosulfan sulfate	ND	ug/L	0.10
Endrin	ND	ug/L	0.10
Endrin aldehyde	ND	ug/L	0.10
Heptachlor	ND	ug/L	0.050
Heptachlor epoxide	ND	ug/L	0.050
Isodrin	ND	ug/L	0.050
Kepone	ND	ug/L	0.10
Methoxychlor	ND	ug/L	0.50
Toxaphene	ND	ug/L	1.0
Dibutyl chlorendate	81	%	--

ND = Not detected
NA = Not applicable

Reported By: William Sullivan Approved By: Greg Gustina

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Appendix IX Herbicides

Method 8150

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 009814-0001-SA Enseco ID: 1078350
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 04 JUN 90 Analyzed: 21 JUN 90

Parameter	Result	Units	Reporting Limit
2,4-D	ND	ug/L	1.2
2,4,5-T	ND	ug/L	0.20
2,4,5-TP (Silvex)	ND	ug/L	0.17
Dalapon	ND	ug/L	5.8
Dinoseb	ND	ug/L	1.0
DCAA	85	%	--

ND = Not detected
NA = Not applicable

Reported By: Susan McCool Approved By: Greg Gustina

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Appendix IX Herbicides

Method 8150

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 009814-0002-SA Enseco ID: 1078352
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 01 JUN 90 Prepared: 04 JUN 90 Analyzed: 21 JUN 90

Parameter	Result	Units	Reporting Limit
2,4-D	ND	ug/L	1.2
2,4,5-T	ND	ug/L	0.20
2,4,5-TP (Silvex)	ND	ug/L	0.17
Dalapon	ND	ug/L	5.8
Dinoseb	ND	ug/L	1.0
DCAA	78	%	--

ND = Not detected
NA = Not applicable

Reported By: Susan McCool Approved By: Greg Gustina

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Triazines by GC

Method 619

Client Name: City Utilities of Springfield
Client ID: Valley Mill Dam
Lab ID: 053102-0001-SA Enseco ID: 151087
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 04 JUN 90 Prepared: 05 JUN 90 Analyzed: 11 JUN 90

Parameter	Result	Units	Reporting Limit
Simazine	ND	ug/L	1.0
Atrazine	ND	ug/L	1.0

ND = Not detected
NA = Not applicable

Reported By: Nancy McDonald Approved By: Lisa Stafford

Enseco
A CORNING Company

Triazines by GC

Method 619

Client Name: City Utilities of Springfield
Client ID: Fulbright Springs
Lab ID: 053102-0002-SA Enseco ID: 151088
Matrix: AQUEOUS Sampled: 31 MAY 90 Received: 01 JUN 90
Authorized: 04 JUN 90 Prepared: 05 JUN 90 Analyzed: 11 JUN 90

Parameter	Result	Units	Reporting Limit
Simazine	ND	ug/L	1.0
Atrazine	ND	ug/L	1.0

ND = Not detected
NA = Not applicable

Reported By: Nancy McDonald Approved By: Lisa Stafford

APPENDIX 10
CITY OF SPRINGFIELD PUBLIC WORKS
WET-WEATHER WATER QUALITY SAMPLING DATA

SITE NO. 1

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-9-93	.53	139.34	1-4-93 (.81)
3) 3-15-93	.70	184.03	3-4-93 (.15)

SITE NO. 2

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-9-93	.53	139.34	1-4-93 (.81)
3) 4-4-93	.70	184.03	4-1-93am (.22)

SITE NO. 3

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-20-93	.81	212.95	1-9-93 (.53)
3) 4-14-93	1.01	265.79	4-7-93 (.20)

SITE NO. 4

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-9-93	.53	139.34	1-4-93 (.81)
3) 4-4-93	.70	184.03	4-1-93am (.22)

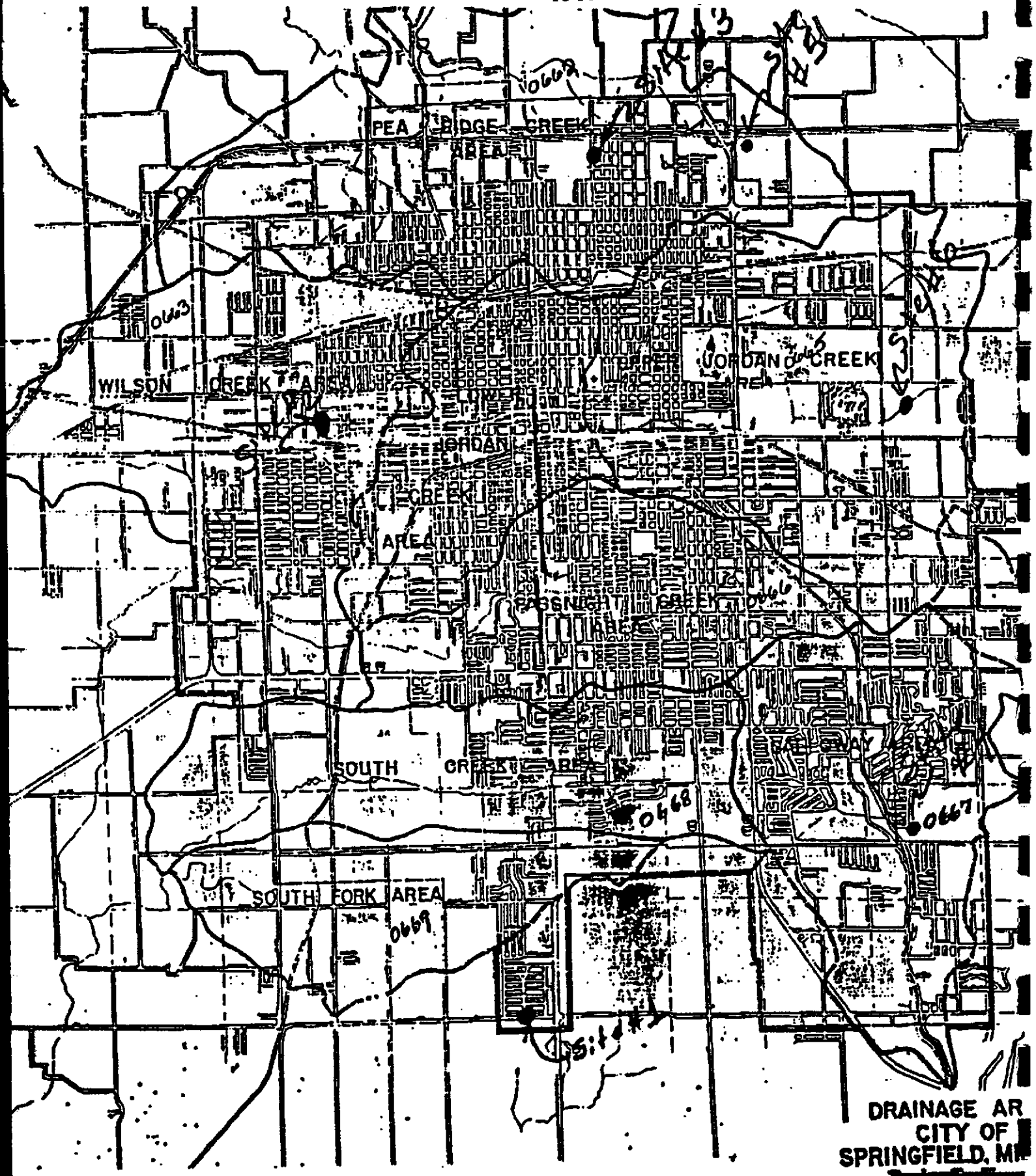
SITE NO. 5

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-9-93	.53	139.34	1-4-93 (.81)
3) 4-4-93	.70	184.03	4-1-93am (.22)

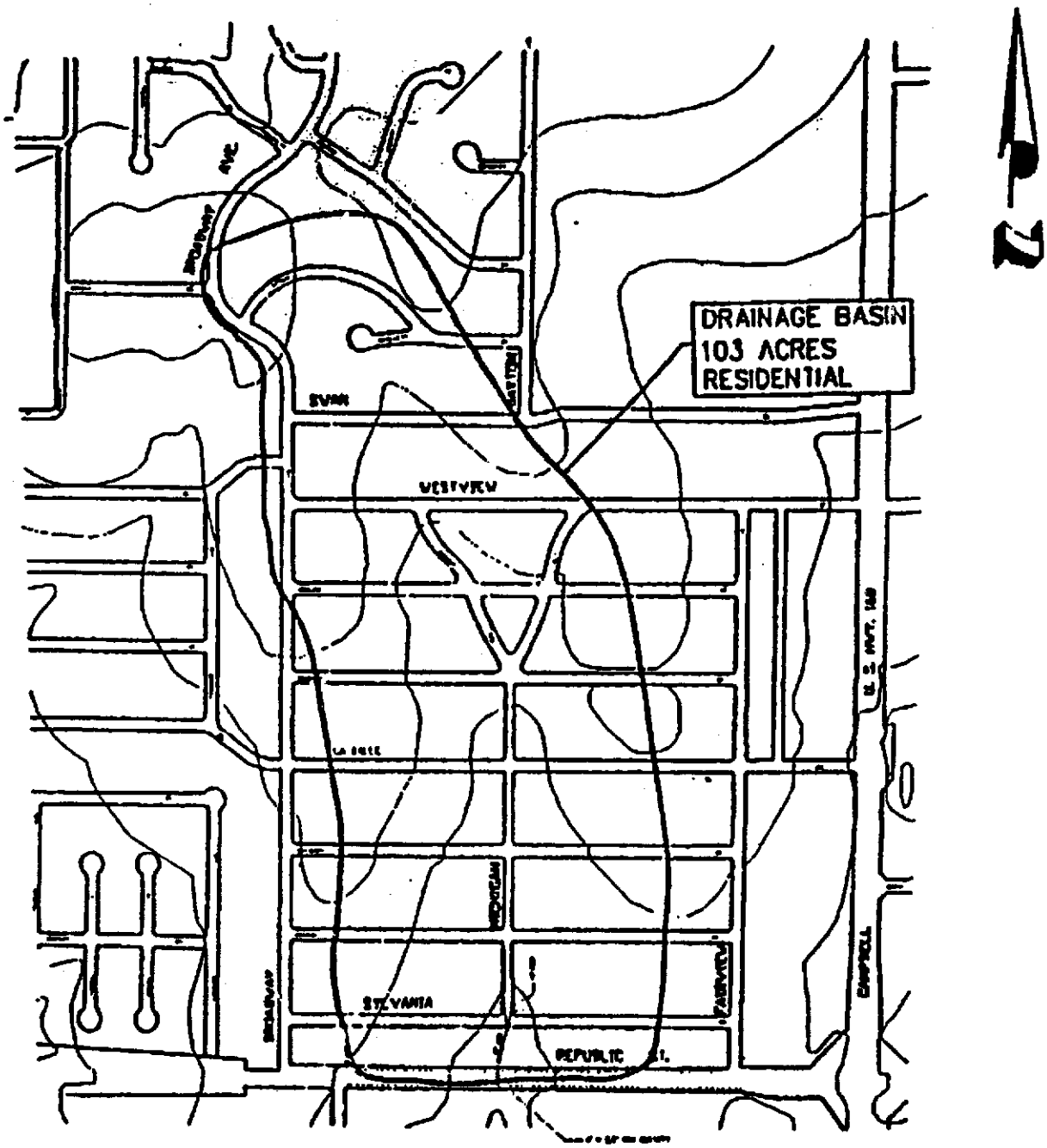
SITE NO. 6

DATE SAMPLE WAS TAKEN	RAINFALL IN INCH.	% OF AVERAGE STORM EVENT	PREVIOUS DATE OF >.1" RAIN
1) 12-9-92	1.11	291.82	11-24-92 (.11)
2) 1-9-93	.53	139.34	1-4-93 (.81)
3) 3-15-93	.70	184.03	3-4-93 (.15)

*** RAINFALL AMOUNTS PROVIDED BY THE NATIONAL WEATHER SERVICE ***
WHICH IS LOCATED AT THE SPRINGFIELD REGIONAL AIRPORT


PEA RIDGE CREEK AREA
WILSON CREEK AREA
JORDAN CREEK AREA
JORDAN CREEK AREA
PASSNIGHT CREEK AREA
SOUTH CREEK AREA
SOUTH FORK AREA
0663
0665
0666
0668
0667
0669
DRAINAGE AR
CITY OF
SPRINGFIELD, MI

SITE NO. 1



$R_v = .45$

STORM WATER ANALYSI. .OR NPDES PERMIT

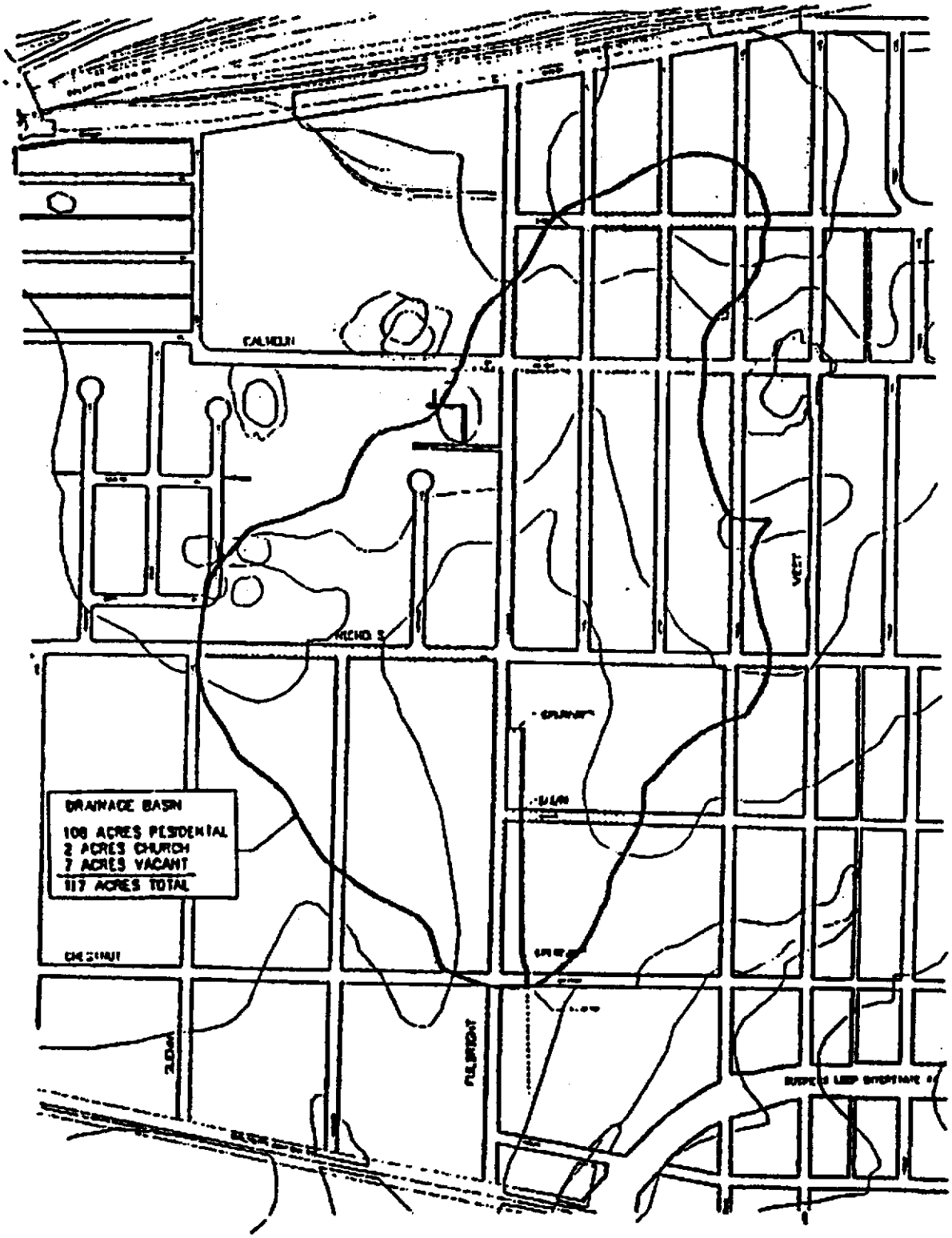
Site #1 - Summary
Residental - Southwest
103 Acres Rv = 0.45

POLLUTANT DETECTED		EVENT MEAN CONCENTRATIONS Storm #1	Storm #2	Storm #3	AVERAGE	ANNUAL POLLUTANT LOAD
Chromium, total		0.003 *	0.003 *	0.007	0.004	2
Zinc, total		0.088	0.008	0.052	0.049	18
Total Dissolved Solids		96	88	40	75	27,864
Total Suspended Solids		24	4	35	21	7,837
Chemical Oxygen Demand		0.50 *	9.70	33.60	14.60	5,448
Biochemical Oxygen Demand		4	2	5	4	1,368
Oil & Grease		20.50	6.96	2.50 *	9.99	3,727
Total Kjeldahl Nitrogen		0.68	0.49	0.88	0.68	255
Ammonia as Nitrogen		0.43	0.41	0.48	0.44	164
Nitrate/Nitrite Nitrogen		0.93	0.80	0.78	0.84	312
Dissolved Phosphorus as P		0.093	0.067	0.046	0.069	26
Total Phosphorus as P		0.129	0.079	0.077	0.095	35
bis (2-Ethylhexyl) Phthalate	ug/l	5,800	2.500 *	2.500 *	3.600	
Fecal Coliform	/100ml	380	1,873	218	824	
Fecal Streptococcus	/100ml	2,220	2,710	762	1,897	
pH		7.570	7.920	8.30	7.6 - 8.3	

NOTE. * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

SITE NO. 2

A-10-5



$$R_V = \frac{(.47 \times 108) + (2 \times .75) + (7 \times .15)}{117} = .46$$

STORM WATER ANALYSIS OR NPDES PERMIT

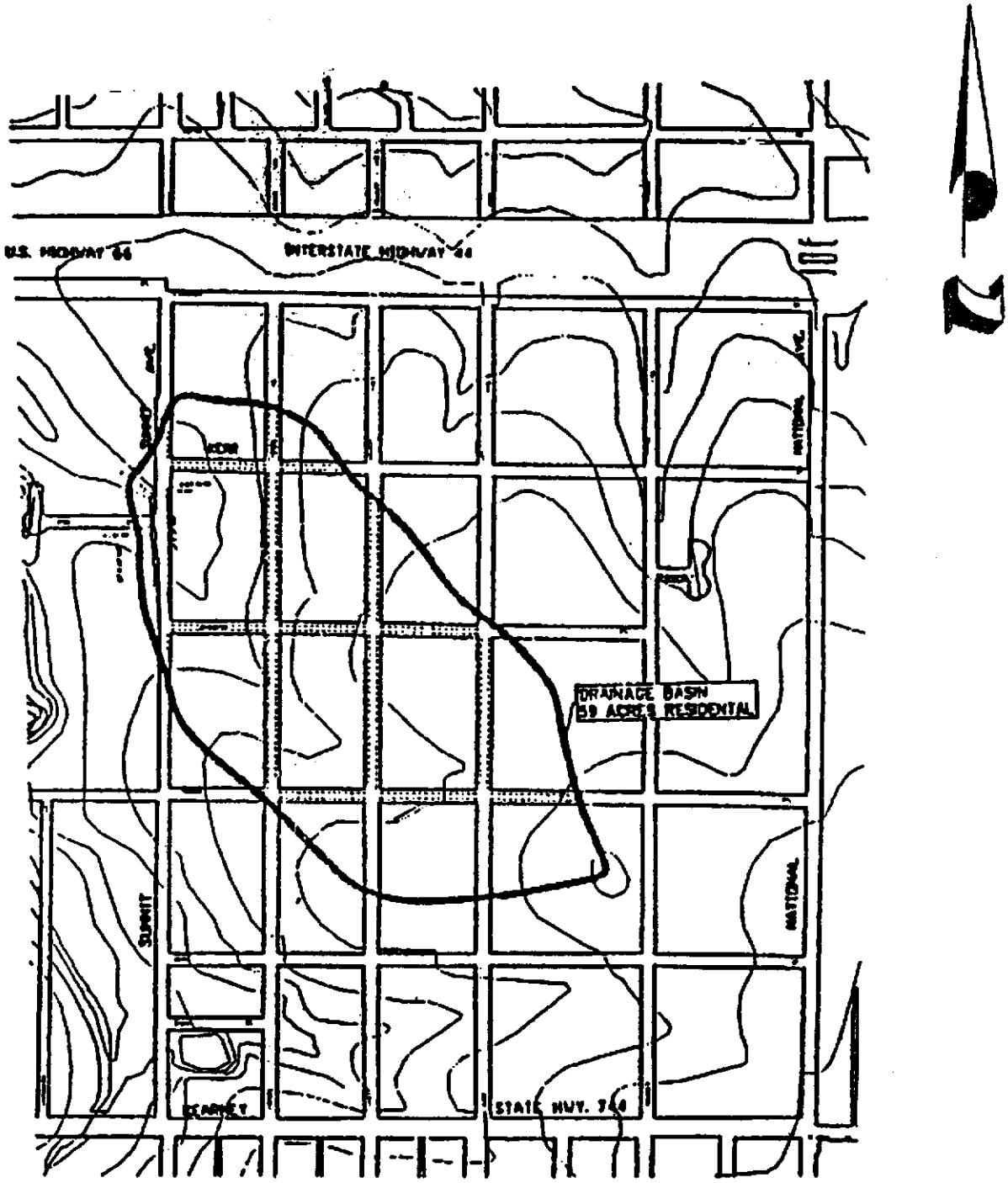
Site #2 - Summary
Residental - West
117 Acres Rv = 0.46

EVENT MEAN CONCENTRATIONS

		Storm #1	Storm #2	Storm #3	AVERAGE	ANNUAL POLLUTANT LOAD
Chromium, total		0.003 *	0.003 *	0.008	0.005	2
Copper, total		0.006	0.009	0.005	0.007	2
Lead, total		0.005 *	0.01	0.02	0.01	4
Nickel, total		0.005 *	0.005 *	0.01	0.01	2
Zinc, Total		0.097	0.031	0.121	0.083	31
Total Dissolved Solids		160	168	134	154	57,469
Total Suspended Solids		42	14	92	49	18,410
Chemical Oxygen Demand		23.20	16.90	66.30	35.47	13,235
Biochemical Oxygen Demand		1	2	7	3	1,244
Oil & Grease		18.80	12.50	8.80	13.37	4,988
Total Kjeldahl Nitrogen		1.28	0.40	1.63	1.10	412
Ammonia as Nitrogen		0.42	0.34	0.33	0.36	136
Nitrate/Nitrite Nitrogen		0.97	0.89	13.40	5.09	1,898
Dissolved Phosphorus as P		0.205	0.121	0.083	0.136	51
Total Phosphorus as P		0.191	0.094	0.232	0.172	64
Fecal Coliform	/100ml	650	167	2,758.000	1,192	
Fecal Streptococcus	/100ml	4,000	3,067	11,727.000	6,265	
pH		7.37	7.90	8.20	7.4 - 8.2	

NOTE: * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

SITE NO. 3



$R_V = 0.45$

RES-NE

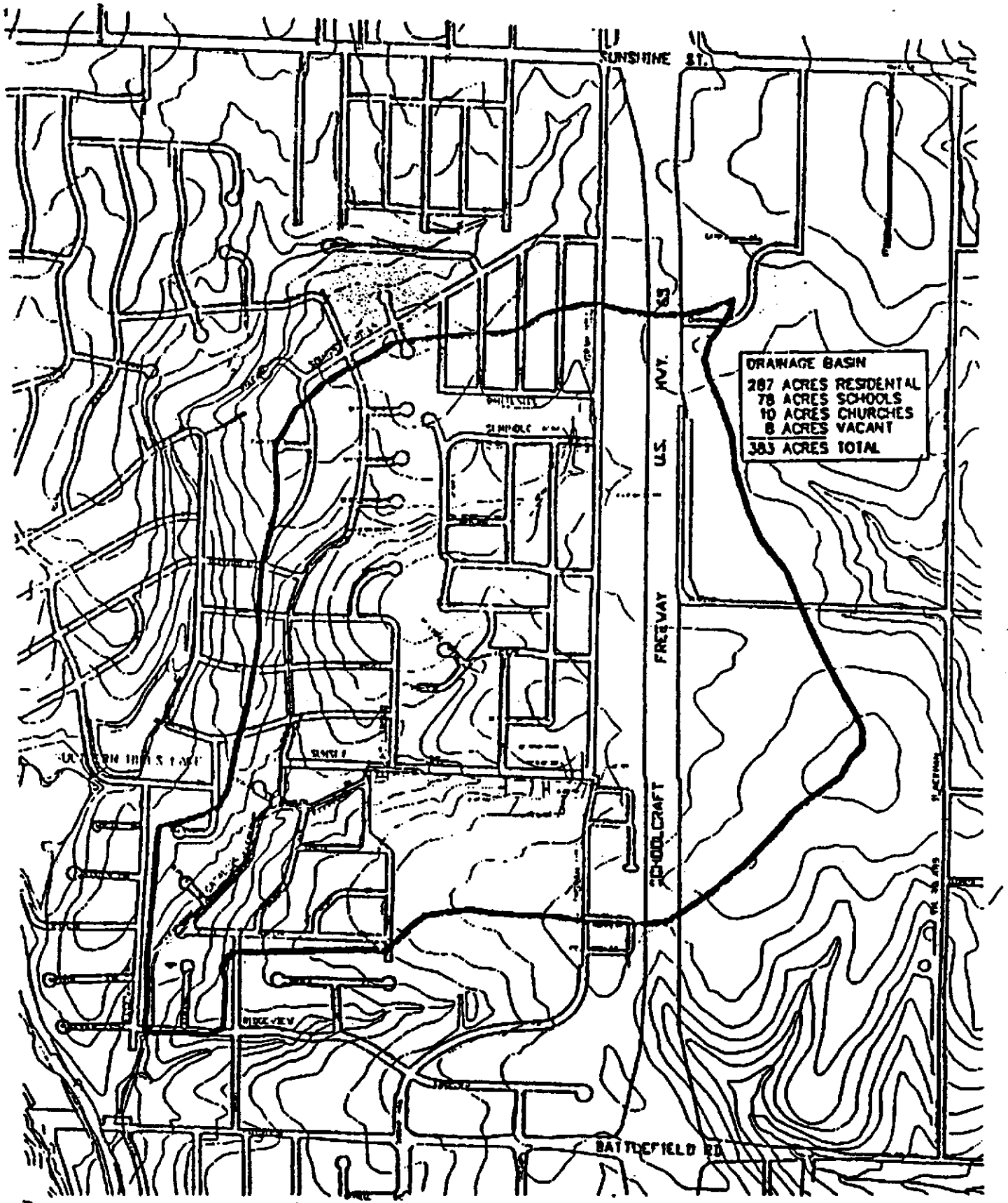
STORM WATER ANALYSI OR NPDES PERMIT

Site #3 - Summary
Residental - North
59 Acres Rv = 0.45

		EVENT MEAN CONCENTRATIONS				ANNUAL POLLUTANT LOAD
		Storm #1	Storm #2	Storm #3	AVERAGE	
Chromium, total		0.003 *	0.013		0.008	3
Copper, total		0.005	0.010		0.008	3
Lead, total		0.005 *	0.03		0.02	7
Nickel, total		0.01	0.01		0.01	4
Silver, total		0.008	0.001		0.005	2
Zinc, total		0.051	0.128		0.090	33
Total Dissolved Solids		168	76	54	103	38,312
Total Suspended Solids		122	200	7	110	40,925
Chemical Oxygen Demand		14.40	19.90	33.80	22.70	8,471
Biochemical Oxygen Demand		0.5 *	6	4	4	1,306
Oil & Grease		7.45	2.50 *	19.00	9.65	3,601
Total Kjeldahl Nitrogen		1.17	0.89	0.93	1.00	372
Ammonia as Nitrogen		0.38	0.26	0.39	0.34	128
Nitrate/Nitrite Nitrogen		0.96	0.22	0.95	0.71	265
Dissolved Phosphorus as P		0.340	0.108	0.186	0	79
Total Phosphorus as P		0.245	0.059	0.244	0	68
Fecal Coliform	/100ml	620	301	2,382	1,101	
Fecal Streptococcus	/100ml	3,380	1,763	10,420	5,188	
pH		8.02	9.00	8.60	8.0 - 9.0	

NOTE: * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

SITE NO. 4



$$R_v = \frac{(.35 \times 287) + (.90 \times 78) + (.75 \times 10) + (.15 \times 8)}{383} = .47$$

RES-SE

STORM WATER ANALYSI OR NPDES PERMIT

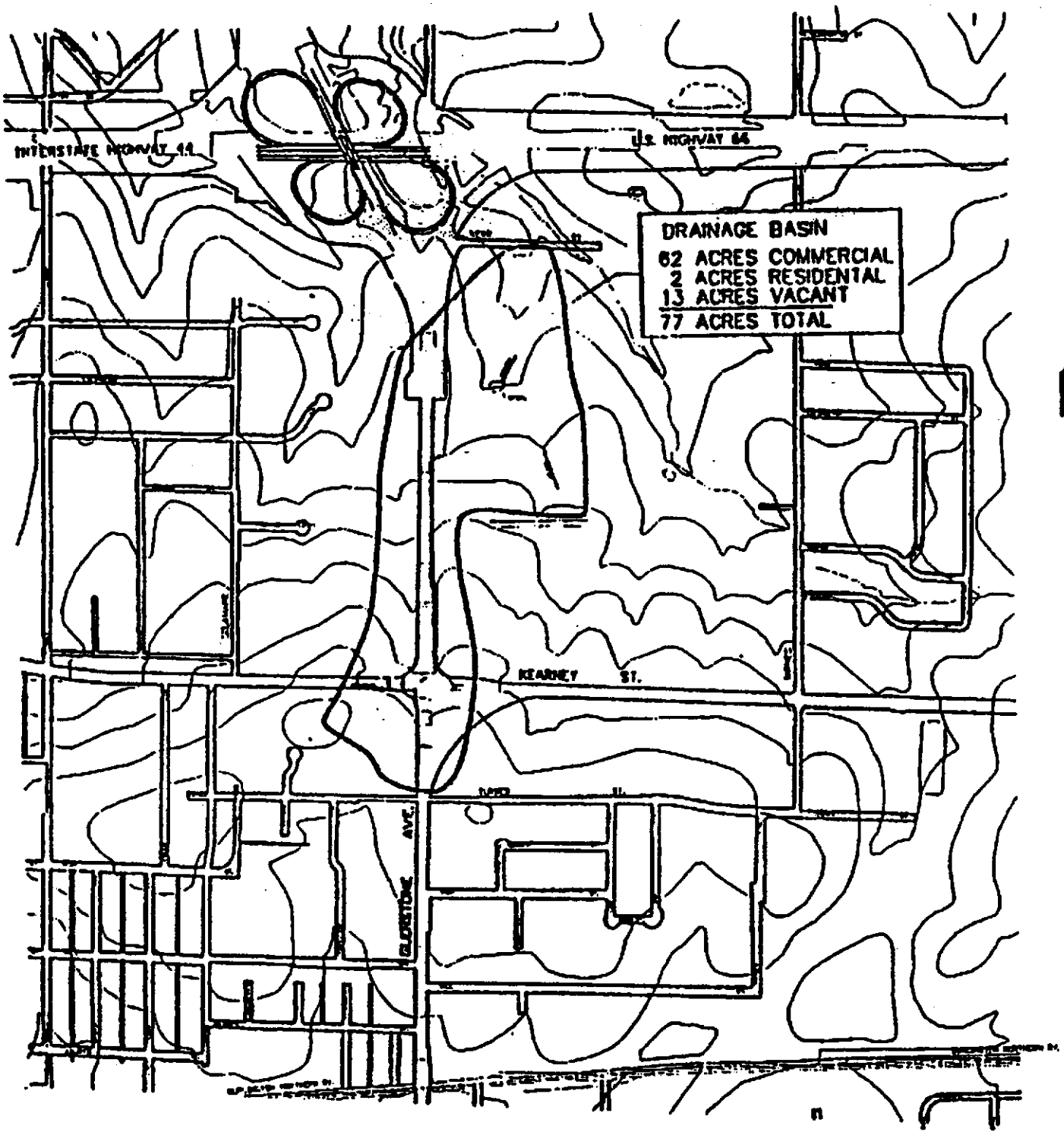
Site #4 - Summary
Residental - Southeast
383 Acres Rv = 0.47

EVENT MEAN CONCENTRATIONS

		Storm #1	Storm #2	Storm #3	AVERAGE	ANNUAL POLLUTANT LOAD
Chromium, total		0.003 *	0.005	0.003 *	0.003	1
Copper, total		0.003 *	0.005	0.003 *	0.003	1
Lead, total		0.005 *	0.01	0.005 *	0.01	2
Nickel, total		0.005 *	0.01	0.01	0.01	3
Silver, total		0.001 *	0.001	0.001 *	0.001	0
Zinc, total		0.058	0.013	0.029	0.033	12
Total Dissolved Solids		260	416	40	239	89,064
Total Suspended Solids		18	9	16	14	5,349
Chemical Oxygen Demand		11.40	9.69	17.40	12.83	4,789
Biochemical Oxygen Demand		1	1	1	1	373
Oil & Grease		8.54	7.58	7.07	7.73	2,885
Total Kjeldahl Nitrogen		0.53	0.30	0.87	0.57	211
Ammonia as Nitrogen		0.30	0.24	0.85	0.46	173
Nitrate/Nitrite Nitrogen		0.97	0.76	0.95	0.89	333
Dissolved Phosphorus as P		0.242	0.069	0.039	0.117	44
Total Phosphorus as P		0.136	0.056	0.094	0.095	36
Fecal Coliform	/100ml	371	188	889	483	
Fecal Streptococcus	/100ml	1,633	410	1,845	1,296	
pH		7.68	8.15	7.30	7.3 - 8.2	

NOTE: * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

SITE NO. 5



$$R_v = \frac{(1 \times 62) + (.35 \times 2) + (.15 \times 13)}{77} = .84$$

STORM WATER ANALYSI. /OR NPDES PERMIT

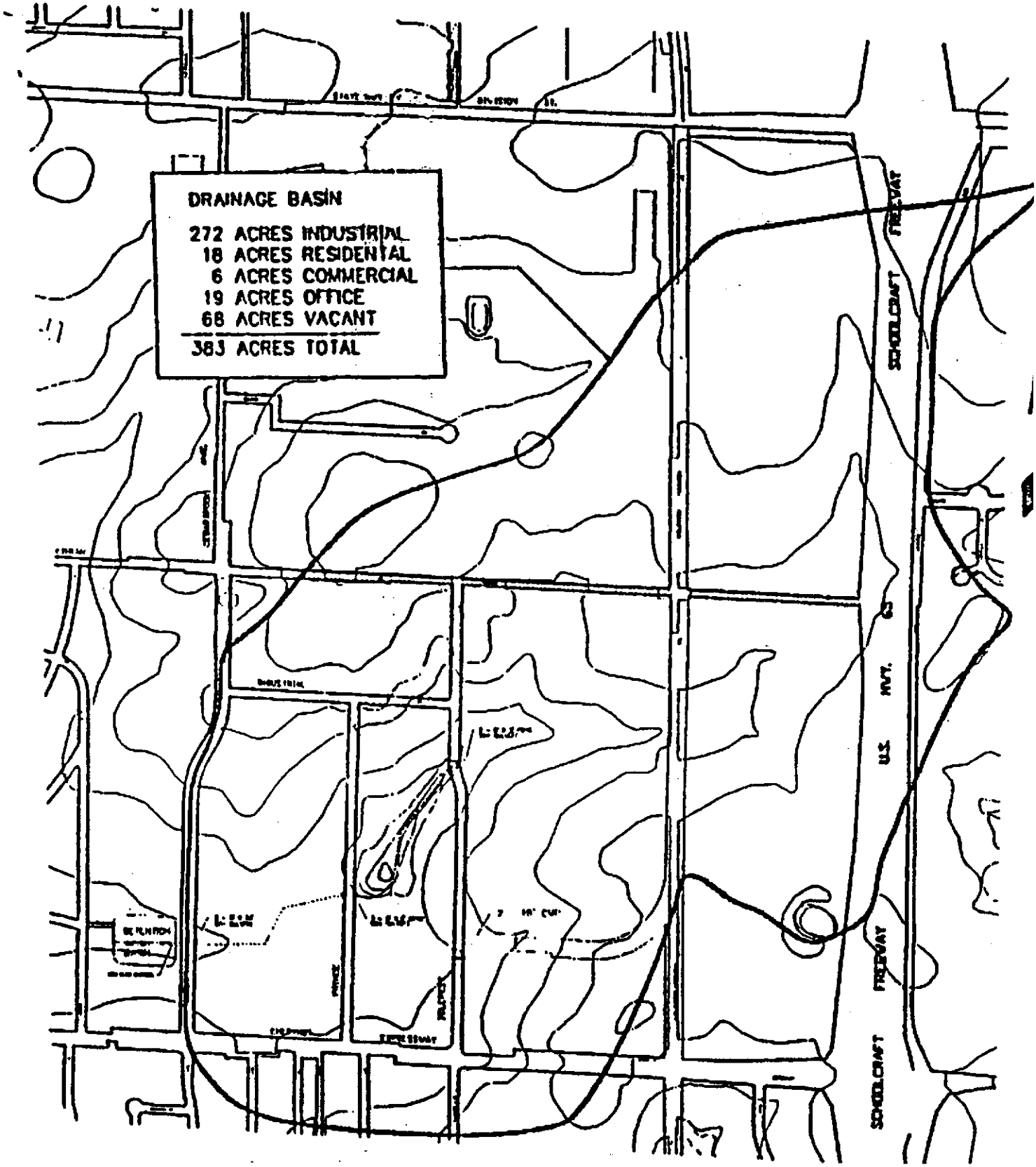
Site #5 - Summary
Commercial
77 Acres Rv = 0.84

EVENT MEAN CONCENTRATIONS

		Storm #1	Storm #2	Storm #3	AVERAGE	ANNUAL POLLUTANT LOAD
Chromium, total		0.003 *	0.012	0.007	0.007	3
Copper, total		0.006	0.007	0.003 *	0.005	2
Lead, total		0.02	0.03	0.01	0.02	7
Nickel, total		0.01	0.005 *	0.005 *	0.01	2
Zinc, total		0.067	0.055	0.144	0.089	33
Total Dissolved Solids		292	484	84	287	106,976
Total Suspended Solids		44	24	28	32	11,942
Chemical Oxygen Demand		10.40	23.70	33.00	22.37	8,347
Biochemical Oxygen Demand		0.05 *	4	4	3	1,001
Oil & Grease		5.44	27.60	15.10	16.05	5,988
Total Kjeldahl Nitrogen		0.76	0.44	0.97	0.72	270
Ammonia as Nitrogen		0.41	0.31	0.64	0.45	169
Nitrate/Nitrite Nitrogen		0.99	0.30	6.70	2.66	994
Dissolved Phosphorus as P		0.126	0.110	0.056	0.097	36
Total Phosphorus as P		0.198	0.078	0.122	0.133	50
Fecal Coliform	/100ml	1,030	342	895	756	
Fecal Streptococcus	/100ml	2,680	2,000	8,568	4,416	
pH		7.92	8.17		7.9 - 8.2	

NOTE: * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

SITE NO. 6



$$Rv = \frac{(272 \times 1) + (18 \times .45) + (6. \times 1) + (19 \times .98) + (68 \times .15)}{383} = .82$$

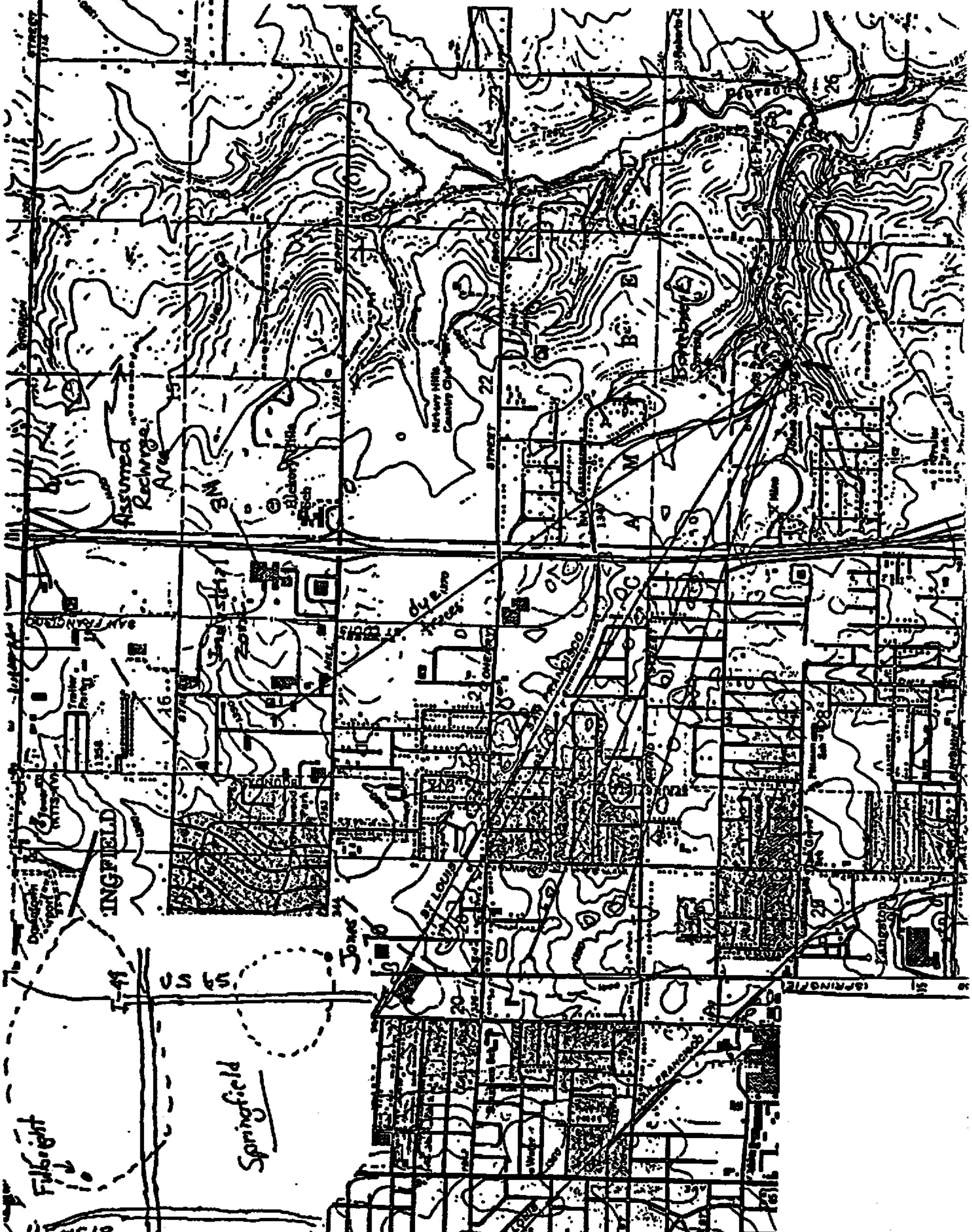
Site #6 - Summary
Industrail
383 Acres Rv = 0.82

EVENT MEAN CONCENTRATIONS

		Storm #1	Storm #2	Storm #3	AVERAGE	ANNUAL POLLUTANT LOAD
Chromium, total		0.003 *	0.012	0.012	0.009	3
Copper, total		0.013	0.009	0.011	0.011	4
Lead, total		0.02	0.02	0.005 *	0.02	6
Nickel, total		0.01	0.01	0.01	0.01	4
Zinc, total		0.219	0.121	0.087	0.142	53
Total Dissolved Solids		508	973	69	517	192,806
Total Suspended Solids		60	34	88	61	22,639
Chemical Oxygen Demand		34.10	23.50	19.10	25.57	9,541
Biochemical Oxygen Demand		2	6	6	5	1,741
Oil & Grease		25.20	8.91	8.28	14.13	5,273
Total Kjeldahl Nitrogen		1.37	0.82	0.98	1.06	394
Ammonia as Nitrogen		0.43	0.67	0.38	0.49	184
Nitrate/Nitrite Nitrogen		1.00	0.77	0.80	0.86	320
Dissolved Phosphorus as P		0.211	0.104	0.107	0.141	52
Total Phosphorus as P		0.265	0.091	0.087	0.148	55
Benzo (b) Fluoranthene	ug/l	6.200	7.100	2.500 *	5.267	2
bis (2-ethylhexyl) Phthalate	ug/l	2.500 *	5.800	2.500 *	3.600	1
Fluoranthene	ug/l	8.400	8.100	2.500 *	6.333	2
Pyrene	ug/l	5.900	6.300	2.500 *	4.900	2
Fecal Coliform	/100ml	310	195	241	249	
Fecal Streptococcus	/100ml	2,047	833	813	1,231	
pH		7.77	8.12	8.50	7.8 - 8.5	

NOTE: * No pollutant detected. Used half the detection limit.
Values in milligrams per liter unless otherwise noted.
Annual pollunt load in pounds per year.

APPENDIX 11
ORGANIC COMPOUND SAMPLING
JONES SPRING AND PEARSON CREEK


Assumed Recharge Area
US 65
Springfield
Fulbright
Jones
INGFIELD
ST LOUIS
22
16
20

JONES BRANCH BEFORE PEARSON

CITY UTILITIES CENTRAL LABORATORY
Volatile Organic Compounds Data Sheet

Date: 10/18/94 Page 3
Sample Number: 9405070 ID: JNC-260
Date Drawn: 10/13/94 Time Drawn: 14:05:00 Drawn By: KBA
Date At Lab: 10/13/94 Time At Lab: 14:41:01 Login By: KBA
Analyzed: 10/13/94 Analyzed By: KBA

TEST	RESULT	ATYPICAL	LO	[AVG]	HI	---EXPECTED---		UNITS
Tetrachloroethene	ND		[*		]	< 0.5	5.0	ug/L
Toluene	ND		[*		]	< 0.5	1000.0	ug/L
1,2,3-Trichlorobenzene	ND		[*		]	< 0.5	100.0	ug/L
1,2,4-Trichlorobenzene	ND		[*		]	< 0.5	100.0	ug/L
1,1,1-Trichloroethane	ND		[*		]	< 0.5	200.0	ug/L
1,1,2-Trichloroethane	ND		[*		]	< 0.5	100.0	ug/L
Trichloroethene	3.5		[		*]	< 0.5	5.0	ug/L
Trichlorofluoromethane	ND		[*		]	< 2.0	100.0	ug/L
1,2,3-Trichloropropane	ND		[*		]	< 0.5	100.0	ug/L
1,2,4-Trimethylbenzene	ND		[*		]	< 0.5	100.0	ug/L
1,3,5-Trimethylbenzene	ND		[*		]	< 0.5	100.0	ug/L
Vinyl Chloride	ND		[*		]	< 0.5	2.0	ug/L
o-Xylene	ND		[*		]	< 0.5	10000.0	ug/L
m & p-Xylene	ND		[*		]	< 0.5	10000.0	ug/L
Total Xylenes	ND		[*		]	< 0.5	10000.0	ug/L

ND = Not Detected

LOWER PEARSON CREEK

CITY UTILITIES CENTRAL LABORATORY
Volatile Organic Compounds Data Sheet

Date: 10/18/94
Sample Number: 9404855
Date Drawn: 10/03/94
Date At Lab: 10/03/94
Analyzed: 10/10/94

Time Drawn: 14:10:00
Time At Lab: 14:53:58

ID: PRC-300
Drawn By: BSN
Login By: BSN
Analyzed By: KBA

TEST	RESULT	ATYPICAL	LO	[AVG]	HI	---EXPECTED---		UNITS
Tetrachloroethene	ND		[*		]	< 0.5	5.0	ug/L
Toluene	ND		[*		]	< 0.5	1000.0	ug/L
1,2,3-Trichlorobenzene	ND		[*		]	< 0.5	100.0	ug/L
1,2,4-Trichlorobenzene	ND		[*		]	< 0.5	100.0	ug/L
1,1,1-Trichloroethane	ND		[*		]	< 0.5	200.0	ug/L
1,1,2-Trichloroethane	ND		[*		]	< 0.5	100.0	ug/L
Trichloroethene	3.5		[		*]	< 0.5	5.0	ug/L
Trichlorofluoromethane	ND		[*		]	< 2.0	100.0	ug/L
1,2,3-Trichloropropane	ND		[*		]	< 0.5	100.0	ug/L
1,2,4-Trimethylbenzene	ND		[*		]	< 0.5	100.0	ug/L
1,3,5-Trimethylbenzene	ND		[*		]	< 0.5	100.0	ug/L
Vinyl Chloride	ND		[*		]	< 0.5	2.0	ug/L
o-Xylene	ND		[*		]	< 0.5	10000.0	ug/L
m & p-Xylene	ND		[*		]	< 0.5	10000.0	ug/L
Total Xylenes	ND		[*		]	< 0.5	10000.0	ug/L

ND = Not Detected

- - - D R A F T - - -

JONES SPRING

CITY UTILITIES CENTRAL LABORATORY
Volatile Organic Compounds Data Sheet

Date: 10/18/94
Sample Number: 9405069
Date Drawn: 10/13/94 Time Drawn: 14:00:00
Date At Lab: 10/13/94 Time At Lab: 14:40:10
Analyzed: 10/13/94
Comments: RN101394

ID: JNS-000
Drawn By: KBA
Login By: KBA
Analyzed By: KBA

TEST	RESULT	ATYPICAL	LO [AVG] HI	---EXPECTED---		UNITS
Benzene	ND		[*]	< 0.5	5.0	ug/L
Bromobenzene	ND		[*]	< 0.5	100.0	ug/L
Bromochloromethane	ND		[*]	< 0.5	100.0	ug/L
Bromodichloromethane	1.7		[*]	< 0.5	100.0	ug/L
Bromoform	ND		[*]	< 0.5	100.0	ug/L
n-Butylbenzene	ND		[*]	< 0.5	100.0	ug/L
sec-Butylbenzene	ND		[*]	< 0.5	100.0	ug/L
tert-Butylbenzene	ND		[*]	< 0.5	100.0	ug/L
Carbon Tetrachloride	ND		[*]	< 0.5	5.0	ug/L
Chlorobenzene	ND		[*]	< 0.5	100.0	ug/L
Chloroform	1.4		[*]	< 0.5	100.0	ug/L
Chloromethane	ND		[*]	< 0.9	100.0	ug/L
2-Chlorotoluene	ND		[*]	< 0.5	100.0	ug/L
4-Chlorotoluene	ND		[*]	< 0.5	100.0	ug/L
Dibromochloromethane	ND		[*]	< 0.5	100.0	ug/L
1,2-Dibromo-3-Chloropropane	ND		[*]	< 3.0	100.0	ug/L
1,2-Dibromoethene	ND		[*]	< 0.5	100.0	ug/L
Dibromomethane	ND		[*]	< 0.5	100.0	ug/L
1,2-Dichlorobenzene	ND		[*]	< 0.5	600.0	ug/L
1,3-Dichlorobenzene	ND		[*]	< 0.5	100.0	ug/L
1,4-Dichlorobenzene	ND		[*]	< 0.5	75.0	ug/L
Dichlorodifluoromethane	ND		[*]	< 2.0	100.0	ug/L
1,1-Dichloroethane	3.3		[*]	< 0.5	5.0	ug/L
1,2-Dichloroethane	ND		[*]	< 0.5	100.0	ug/L
1,1-Dichloroethene	3.9		[*]	< 0.5	7.0	ug/L
cis-1,2-Dichloroethene	ND		[*]	< 0.5	70.0	ug/L
trans-1,2-Dichloroethene	ND		[*]	< 0.5	100.0	ug/L
1,2-Dichloropropane	ND		[*]	< 0.5	5.0	ug/L
1,3-Dichloropropane	ND		[*]	< 0.5	100.0	ug/L
2,2-Dichloropropane	ND		[*]	< 1.0	100.0	ug/L
1,1-Dichloropropene	ND		[*]	< 0.5	100.0	ug/L
cis-1,3-Dichloropropene	ND		[*]	< 0.5	100.0	ug/L
trans-1,3-Dichloropropene	ND		[*]	< 0.5	100.0	ug/L
Ethylbenzene	ND		[*]	< 0.5	700.0	ug/L
Hexachlorobutadiene	ND		[*]	< 1.0	100.0	ug/L
Isopropylbenzene	ND		[*]	< 0.5	100.0	ug/L
p-Isopropyltoluene	ND		[*]	< 0.5	100.0	ug/L
Methylene Chloride	ND		[*]	< 0.5	100.0	ug/L
Naphthalene	ND		[*]	< 1.0	100.0	ug/L
n-Propylbenzene	ND		[*]	< 0.5	100.0	ug/L
Styrene	ND		[*]	< 0.5	100.0	ug/L
1,1,1,2-Tetrachloroethane	ND		[*]	< 0.5	100.0	ug/L
1,1,2,2-Tetrachloroethane	ND		[*]	< 0.5	100.0	ug/L

ND = Not Detected

CITY UTILITIES CENTRAL LABORATORY
Volatile Organic Compounds Data Sheet

Date: 10/18/94
Sample Number: 9405069
Date Drawn: 10/13/94 Time Drawn: 14:00:00
Date At Lab: 10/13/94 Time At Lab: 14:40:10
Analyzed: 10/13/94

ID: JNS-000
Drawn By: KBA
Login By: KBA
Analyzed By: KBA

TEST	RESULT	ATYPICAL	LO [AVG] HI	---EXPECTED---		UNIT
Tetrachloroethene	4.5		[*]	< 0.5	5.0	ug/L
Toluene	ND		[*]	< 0.5	1000.0	ug/L
1,2,3-Trichlorobenzene	ND		[*]	< 0.5	100.0	ug/L
1,2,4-Trichlorobenzene	ND		[*]	< 0.5	100.0	ug/L
1,1,1-Trichloroethane	7.4		[*]	< 0.5	200.0	ug/L
1,1,2-Trichloroethane	ND		[*]	< 0.5	100.0	ug/L
Trichloroethene		11.5	[ ]>	< 0.5	5.0	ug/L
Trichlorofluoromethane	ND		[*]	< 2.0	100.0	ug/L
1,2,3-Trichloropropane	ND		[*]	< 0.5	100.0	ug/L
1,2,4-Trimethylbenzene	ND		[*]	< 0.5	100.0	ug/L
1,3,5-Trimethylbenzene	ND		[*]	< 0.5	100.0	ug/L
Vinyl Chloride	ND		[*]	< 0.5	2.0	ug/L
o-Xylene	ND		[*]	< 0.5	10000.0	ug/L
m & p-Xylene	ND		[*]	< 0.5	10000.0	ug/L
Total Xylenes	ND		[*]	< 0.5	10000.0	ug/L

ND = Not Detected

LABORATORY SERVICES PROGRAM
RESULT OF SAMPLE ANALYSIS

Sample No. 89-1812

ported to: LARRY ALDERSON
filiation: EER

Date: 12/08/89
Project Code: 3535/3000

mple Description:
3M CO. SITE
WATER SAMPLE FROM JONES SPRING

ollected by: LARRY ALDERSON
ffiliation: EER

Date: 08/16/89

PARAMETERS	RESULTS
crolein	Not analyzed
Acrylonitrile	Not analyzed
Acetone	< 20 ug/L
Benzene	< 5.0 ug/L
Bromomethane	< 5.0 ug/L
Bromodichloromethane	< 5.0 ug/L
Bromoform	< 5.0 ug/L
2-Butanone	22 ug/L
Carbon Disulfide	< 5.0 ug/L
Carbon Tetrachloride	< 5.0 ug/L
Chlorobenzene	< 5.0 ug/L
Chloroethane	< 5.0 ug/L
2-Chloroethylvinyl ether	Not Analyzed
Chloroform	< 5.0 ug/L
Chloromethane	< 5.0 ug/L
Dibromochloromethane	< 5.0 ug/L
1,1-Dichloroethane	< 5.0 ug/L
1,2-Dichloroethane	< 5.0 ug/L
1,1-Dichloroethylene	< 5.0 ug/L
1,2-Dichloroethylene	< 5.0 ug/L
1,2-Dichloropropane	< 5.0 ug/L
cis-1,3-Dichloropropene	< 5.0 ug/L
trans-1,3-Dichloropropene	< 5.0 ug/L
Ethylbenzene	< 5.0 ug/L
2-Hexanone	< 20 ug/L
Methylene Chloride	< 20 ug/L
4-Methyl-2-Pentanone	< 20 ug/L

Page 2
Sample no. 89-1812
Date 12/08/89

PARAMETERS	RESULTS
Styrene	< 5.0 ug/L
1,1,2,2-Tetrachloroethane	< 5.0 ug/L
Tetrachloroethylene	< 5.0 ug/L
1,1,1-Trichloroethane	< 5.0 ug/L
1,1,2-Trichloroethane	< 5.0 ug/L
Trichloroethylene	14 ug/L
Trichlorofluoromethane	Not analyzed
Toluene	< 5.0 ug/L
Total Xylenes	< 10 ug/L
Vinyl Acetate	< 20 ug/L
Vinyl Chloride	< 5.0 ug/L

COMMENTS: Analyzed by GC/MS at the Missouri Department of Natural Resources Laboratory.

2-Chlorophenol	< 5.0 ug/L
2,4-Dichlorophenol	< 5.0 ug/L
2,4-Dimethylphenol	< 5.0 ug/L
4,6-Dinitro-o-cresol	< 5.0 ug/L
2,4-Dinitrophenol	< 5.0 ug/L
2-Methylphenol	Not Analyzed
3-Methylphenol	Not Analyzed
4-Methylphenol	Not Analyzed
2-Nitrophenol	< 5.0 ug/L
4-Nitrophenol	< 5.0 ug/L
4-Chloro-3-methylphenol	Not Analyzed
Pentachlorophenol	< 5.0 ug/L
Phenol	< 5.0 ug/L
2,4,5-Trichlorophenol	Not Analyzed
2,4,6-Trichlorophenol	< 5.0 ug/L

COMMENTS: Analyzed by GC/MS at Continental Analytical Services, Inc.

Acenaphthene	< 5.0 ug/L
Acenaphthylene	< 5.0 ug/L
Aniline	Not Analyzed
Anthracene	< 5.0 ug/L
Benzo(a)anthracene	< 5.0 ug/L
Benzo(a)pyrene	< 5.0 ug/L
Benzo(b)fluoranthene	< 5.0 ug/L

APPENDIX 12
NATIONAL URBAN RUNOFF PROGRAM
WATER DATA SUMMARY
DECEMBER 1983

TABLE 6-21. SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: PERCENTAGE OF SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[1]

Pollutant	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances (%)[3]						
			None	FA	FC	OL	NH	HC[4]	Dw
I. PESTICIDES									
3. α-Hexachlorocyclohexane	20	21/106						8,18,20	
6. γ-Hexachlorocyclohexane (Lindane)	15	15/100			8			0,10,15	
7. Chlordane	17	7/42		2	17			17,17,17	
12. α-Endosulfan	19	9/49			10				
II. METALS AND INORGANICS									
22. Antimony	13	14/106	1						
23. Arsenic	52	46/87						52,52,52	1
25. Beryllium	12	11/94			6*			12,12,12	
26. Cadmium[5]	48	44/91		8	48		1		;
27. Chromium[5,6]	50	47/81			1*				1
28. Copper[5]	91	79/87		47	82				
29. Cyanides	23	16/71		3	22		4		
30. Lead[5]	94	75/80		23	94		73		73
32. Nickel[5]	43	38/91			5		21		
33. Selenium	11	10/88			5		10		10
36. Zinc[5]	94	88/94		14	77				
IV. HALOGENATED ALIPHATICS									
47. Methane, dichloro-	11	3/28						0,0,11	
VII. PHENOLS AND CRESOLS									
90. Phenol	14	13/91	1						
94. Phenol, pentachloro-	19	21/111		1*	11*	1			
96. Phenol, 4-nitro-	10	11/107	1						
VIII. PHTHALATE ESTERS									
106. Phthalate, bis(2-ethylhexyl)	22	15/69			22*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS									
115. Chrysene	10	11/109						10,10,10	
117. Fluoranthene	16	17/109	1						
121. Phenanthrene	12	13/110						12,12,12	
122. Pyrene	15	16/110						15,15,15	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

1 Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

2 Number of times detected/number of acceptable samples.

3 FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
NH = Non-Carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
Dw = Primary drinking water criterion.

4 Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

5 Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

6 Different criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the less toxic trivalent form.

RESULTS

OF THE

NATIONWIDE URBAN RUNOFF PROGRAM

December, 1983

VOLUME I - FINAL REPORT

Water Planning Division

U.S. Environmental Protection Agency

Washington, D.C. 20460

National Technical Information Service (NTIS)
Accession Number: PB84-185552

TABLE - :- SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1]

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/l)*
I. PESTICIDES			
1. Acrolein	Holding times exceeded		
2. Aldrin	6,7,26	6	0.0027-0.1M
3. α-Hexachlorocyclohexane (α-BHC) (Alpha)	7,8,22,26	20	0.0027-0.1M
4. β-Hexachlorocyclohexane (β-BHC) (Beta)	7,8	5	0.018-0.1M
5. γ-Hexachlorocyclohexane (γ-BHC) (Gamma) (Lindane)	7,8,22,26	15	0.007-0.1M
6. δ-Hexachlorocyclohexane (δ-BHC) (Delta)	7,26	6	0.004-0.1M
7. Chlordane	2,8,21,26	17	0.01L-10
8. DDD	Not detected		
9. DDE	26	6	0.007-0.027
10. DDT	7	1	0.1M
11. Dieldrin	26,27	6	0.007-0.1
12. α-Endosulfan (Alpha)	7,26,27	19	0.008-0.2
13. β-Endosulfan (Beta)	Not detected		
14. Endosulfan sulfate	Not detected		
15. Endrin	Not detected		
16. Endrin aldehyde	Not detected		
17. Heptachlor	7,8,27	6	0.01-0.1M
18. Heptachlor epoxide	7,26	2	0.0037-0.1M
19. Isophorone	7	3	10M
20. TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin)	Not included in NURP program		
21. Toxaphene	Not detected		
II. METALS AND INORGANICS			
22. Antimony	7,24,26	13	2.6-23A
23. Arsenic	2,3,7,12,19,20,21,22,26,27	52	1-50.5
24. Asbestos	Not included in NURP program		
25. Beryllium	7,12,20,21	12	1-49
26. Cadmium	1,2,3,7,12,20,21,27	48	0.1M-14
27. Chromium	1,2,7,8,12,17,19,20,21,22,26, 27,28	58	1-190
28. Copper	1,2,3,4,7,8,12,17,19,20,21,22, 23,26,27,28	91	1L-100
29. Cyanides	4,8,19,22,26,27	23	2-300
30. Lead	1,2,3,4,7,8,12,17,19,20,21,22, 26,28	94	6-460
31. Mercury	7,20,28	9	0.6-1.2
32. Nickel	2,3,7,12,20,21,26,27	43	1-182
33. Selenium	7,19,23	11	2-77
34. Silver	3,17,27	7	0.2M-0.8
35. Thallium	7	6	1-14
36. Zinc	1,2,3,7,12,17,19,20,21,22, 23,27,28	94	10-2400
III. PCBs AND RELATED COMPOUNDS			
37. PCB-1016 (Aroclor 1016)	Not detected		
38. PCB-1221 (Aroclor 1221)	Not detected		
39. PCB-1232 (Aroclor 1232)	Not detected		
40. PCB-1242 (Aroclor 1242)	Not detected		
41. PCB-1248 (Aroclor 1248)	Not detected		
42. PCB-1254 (Aroclor 1254)	Not detected		
43. PCB-1260 (Aroclor 1260)	2	1	0.03
44. 2-Chloronaphthalene	Not detected		

TABLE 6-19. SUMMARY — ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/l)[4]
IV. HALOGENATED ALIPHATICS			
45. Methane, bromo- (methyl bromide)	Not detected		
46. Methane, chloro- (methyl chloride)	Not detected		
47. Methane, dichloro- (methylene chloride)	4,17,22	11	5-14.5A
48. Methane, chlorodibromo-	28	1	2
49. Methane, dichlorobromo-	28	1	2
50. Methane, tribromo - (bromoform)	28	1	1
51. Methane, trichloro- (chloroform)	4,17,20,22,23,27,28	9	0.2T-12L
52. Methane, tetrachloro- (carbon tetrachloride)	4,28	3	1-2
53. Methane, trichlorofluoro-[5]	2,4,24,28	5	0.6T-27
54. Methane, dichlorodifluoro- (Freon-12)[5]	Not detected		
55. Ethane, chloro-	Not detected		
56. Ethane, 1,1-dichloro-	4,28	3	1.5A-3
57. Ethane, 1,2-dichloro-	28	1	4
58. Ethane, 1,1,1-trichloro-	4,2,7,22,24	6	1.6-10M
59. Ethane, 1,1,2-trichloro-	28	2	2-3
60. Ethane, 1,1,2,2-tetrachloro-	4	2	26-3
61. Ethane, hexachloro-	Not detected		
62. Ethene, chloro- (vinyl chloride)	Not detected		
63. Ethene, 1,1-dichloro-	28	2	1.6-4
64. Ethene, 1,2-trans-dichloro-	20,28	4	1-3
65. Ethene, trichloro-	2,4,8,24,28	6	0.3T-12
66. Ethene, tetrachloro-	8,17,22,28	5	1M-43
67. Propene, 1,2-dichloro-	28	1	3
68. Propene, 1,3-dichloro-	28	2	1-2
69. Butadiene, hexachloro-	Not detected		
70. Cyclopentadiene, hexachloro-	Standard methods inappropriate		
V. ETHERS			
71. Ether, bis(chloromethyl)[5]	Not detected		
72. Ether, bis(2-chloroethyl)	Not detected		
73. Ether, bis(2-chloroisopropyl)	Not detected		
74. Ether, 2-chloroethyl vinyl	Not detected		
75. Ether, 4-bromophenyl phenyl	Not detected		
76. Ether, 4-chlorophenyl phenyl	Not detected		
77. Bis(2-chloroethoxy) methane	Not detected		
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)			
78. Benzene	4,17,27	4	1-13
79. Benzene, chloro-	7,20,26,28	5	16-10M
80. Benzene, 1,2-dichloro-	Not detected		
81. Benzene, 1,3-dichloro-	Not detected		
82. Benzene, 1,4-dichloro-	Not detected		
83. Benzene, 1,2,4-trichloro-	Not detected		
84. Benzene, hexachloro-	Not detected		
85. Benzene, ethyl-	4,8,17,20,26,28	6	1-2
86. Benzene, nitro-	Not detected		
87. Toluene	4,17	3	3-9
88. Toluene, 2,4-dinitro-	Not detected		
89. Toluene, 2,6-dinitro	Not detected		

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/L)[4]
VII. PHENOLS AND CRESOLS			
90. Phenol	4,7,26	34	1L-13T
91. Phenol, 2-chloro-	28	1	2
92. Phenol, 2,4-dichloro-	Not detected		
93. Phenol, 2,4,6-trichloro-	Not detected		
94. Phenol, pentachloro-	4,8,19,20,26,27,28	39	1T-11S
95. Phenol, 2-nitro-	8	1	1M
96. Phenol, 4-nitro-	4,7,8,20,26,28	10	1T-37
97. Phenol, 2,4-dinitro-	Not detected		
98. Phenol, 2,4-dimethyl-	4,7,8,26	8	1T-18M
99. m-Cresol, p-chloro-	4	1	1.5A
100. o-Cresol 4,6-dinitro-	Not detected		
VIII. PHTHALATE ESTERS			
101. Phthalate, dimethyl	8	1	1L
102. Phthalate, diethyl	3,4,17,20,21	6	1-10M
103. Phthalate, di-n-butyl	4,22,24	6	0.5T-11
104. Phthalate, di-n-octyl	8,20,26,27,28	6	0.4T-86
105. Phthalate, bis(2-ethylhexyl)	4,12,19,22,21,26	22	47-62
106. Phthalate, butyl benzyl	2,8,26	6	1-10M
IX. POLYCYCLIC AROMATIC HYDROCARBONS			
107. Acenaphthene	Not detected		
108. Acenaphthylene	Not detected		
109. Anthracene	2,17,20,21,26,28	7	1-10M
110. Benzo (a) anthracene	2,21,27	4	1-10M
111. Benzo (b) fluoranthene	26,27	5	1-5
112. Benzo (k) fluoranthene	2,21,27	3	4-14
113. Benzo (g,h,i) perylene	21	1	5
114. Benzo (a) pyrene	2,21,26,27	6	1-10M
115. Chrysene	2,7,17,21,26,27	10	0.6T-10M
116. Dibenzo (a,h) anthracene	21	1	1T
117. Fluoranthene	2,8,12,17,21,26,27,28	16	0.3T-21
118. Fluorene	28	1	1
119. Indeno (1,2,3-c,d) pyrene	21	1	4
120. Naphthalene	4,24,26,28	9	0.8T-2.3
121. Phenanthrene	2,8,17,20,21,26,27,28	12	0.3T-10M
122. Pyrene	2,3,8,12,17,21,26,27,28	15	0.3T-16

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY [illegible] FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (ug/L)[4]
E. NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS			
123. Nitrosamine, dimethyl (DMN)	Standard methods inappropriate		
124. Nitrosamine, diphenyl	Standard methods inappropriate		
125. Nitrosamine, di-n-propyl	Not detected		
126. Benzidine	Standard methods inappropriate		
127. Benzidine, 3,3'-dichloro-	Not detected		
128. Hydrazine, 1,2-diphenyl-	Standard methods inappropriate		
129. Acrylonitrile	Holding times exceeded		

[1] Based on 121 sample results received as of 9/30/83, adjusted for quality control review.

[2] Cities from which data are available:

1. Durham, NH
2. Lake Quinsigamond, MA
3. Mystic River, MA
4. Long Island, NY
7. Washington, DC
8. Baltimore, MD
12. Knoxville, TN
17. Glen Ellyn, IL
19. Austin, TX
20. Little Rock, AR
21. Kansas City, KS
22. Denver, CO
23. Salt Lake City, UT
24. Rapid City, SD
26. Fresno, CA
27. Bellevue, WA
28. Eugene, OR

Numbering of cities conforms to NURP convention.

[3] Percentages rounded to nearest whole number.

[4] Some reported concentrations are qualified by STORET quality control remark codes, to wit: A = Value reported is the mean of two or more determinations; G = Value reported is the maximum of two or more determinations; L = Actual value is known to be greater than value given; M = Presence of material verified but not quantified; T = Value reported is less than criteria of detection. One value in this column indicates one positive observation or that all observations were equal.

[5] No longer included as a priority pollutant.

TABLE 6-20. MOST FREQUENTLY DETECTED PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 75 Percent or More of the NURP Samples

Inorganics	Organics
30. Lead (94%)	None
36. Zinc (94%)	
28. Copper (91%)	

Priority Pollutants Detected in 50 percent to 74 percent of the NURP Samples

Inorganics	Organics
27. Chrominum (58%)	None
23. Arsenic (52%)	

Priority Pollutants Detected in 20 percent to 49 percent of the NURP Samples

Inorganics	Organics
26. Cadmium (48%)	105. Bis(2-ethylhexyl) phthalate (22%)
32. Nickel (43%)	3. α-Hexachlorocyclohexane (20%)
29. Cyanides (23%)	

Priority Pollutants Detected in 10 percent to 19 percent of the NURP Samples

Inorganics	Organics
22. Antimony (13%)	12. α-Endosulfan (19%)
25. Beryllium (12%)	94. Pentachlorophenol (19%)
33. Selenium (11%)	7. Chlordane (17%)
	5. γ-Hexachlorocyclohexane (Lindane) (15%)
	122. Pyrene (15%)
	90. Phenol (14%)
	121. Phenanthrene (12%)
	47. Dichloromethane (methylene chloride) (11%)
	96. 4-Nitrophenol (10%)
	115. Chrysene (10%)
	117. Fluoranthene (16%)

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review. Does not include special metals samples.

TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 1 percent to 9 percent of the NURP Samples

51. Trichloromethane (9%)
120. Naphthalene (9%)
98. 2,4-Dimethyl phenol (8%)
109. Anthracene (7%)
2. Aldrin (6%)
6. δ-Hexachlorocyclohexane (6%)
9. DDE (6%)
11. Dieldrin (6%)
17. Heptachlor (6%)
58. 1,1,1-Trichloroethane (6%)
65. Trichloroethene (6%)
85. Ethylbenzene (6%)
102. Diethyl phthalate (6%)
103. Di-n-butyl phthalate (6%)
104. Di-n-octyl phthalate (6%)
106. Butyl benzyl phthalate (6%)*
114. Benzo(a)pyrene (6%)
4. β-Hexachlorocyclohexane (5%)
53. Trichlorofluoromethane (5%)[2]
66. Tetrachloroethene (5%)
78. Benzene (5%)
79. Chlorobenzene (5%)
111. Benzo(b)fluoranthene (5%)*
64. 1,2-trans-dichloroethene (4%)
110. Benzo(a)anthracene (4%)
19. Isophorone (3%)
52. Tetrachloromethane (carbon tetrachloride) (3%)
56. 1,1-Dichloroethane (3%)
87. Toluene (3%)
112. Benzo(k)fluoranthene (3%)
18. Heptachlor epoxide (2%)*
59. 1,1,2-Trichloroethane (2%)*
60. 1,1,2,2-Tetrachloroethane (2%)*
63. 1,1-Dichloroethene (2%)
68. 1,3-Dichloropropene (2%)*
113. Benzo(g,h,i)perylene (2%)
10. DDT (1%)*
43. PCB-1260 (1%)*
48. Chlorodibromomethane (1%)*
49. Dichlorobromomethane (1%)*
50. Tribromomethane (bromoform) (1%)*
57. 1,2-Dichloroethane (1%)*
67. 1,2-Dichloropropane (1%)*
91. 2-Chlorophenol (1%)*
95. 2-Nitrophenol (1%)*
99. p-Chloro-m-creosol (1%)*
101. Dimethyl phthalate (1%)*
116. Dibenzo(a,h)anthracene (1%)*
118. Fluorene (1%)*
119. Indeno(1,2,3-cd)pyrene (1%)*

TABLE 6-21. SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: PERCENTAGE OF SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[1]

Pollutant	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances (%)[3]						
			None	FA	FC	OL	NH	HC[4]	Dw
I. PESTICIDES									
3. α-Hexachlorocyclohexane	20	21/106						8,18,20	
6. γ-Hexachlorocyclohexane (Lindane)	15	15/100			8			0,10,15	
7. Chlordane	17	7/42		2	17			17,17,17	
12. α-Endosulfan	19	9/49			10				
II. METALS AND INORGANICS									
22. Antimony	13	14/106	1						
23. Arsenic	52	46/87						52,52,52	1
25. Beryllium	12	11/94			6*			12,12,12	
26. Cadmium[5]	48	44/91		8	48		1		;
27. Chromium[5,6]	50	47/81			1*				1
28. Copper[5]	91	79/87		47	82				
29. Cyanides	23	16/71		3	22		4		
30. Lead[5]	94	75/80		23	94		73		73
32. Nickel[5]	43	38/91			5		21		
33. Selenium	11	10/88			5		10		10
36. Zinc[5]	94	88/94		14	77				
IV. HALOGENATED ALIPHATICS									
47. Methane, dichloro-	11	3/28						0,0,11	
VII. PHENOLS AND CRESOLS									
90. Phenol	14	13/91	1						
94. Phenol, pentachloro-	19	21/111		1*	11*	1			
96. Phenol, 4-nitro-	10	11/107	1						
VIII. PHTHALATE ESTERS									
106. Phthalate, bis(2-ethylhexyl)	22	15/69			22*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS									
115. Chrysene	10	11/109						10,10,10	
117. Fluoranthene	16	17/109	1						
121. Phenanthrene	12	13/110						12,12,12	
122. Pyrene	15	16/110						15,15,15	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

1 Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

2 Number of times detected/number of acceptable samples.

3 FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
NH = Non-Carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
Dw = Primary drinking water criterion.

4 Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

5 Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

6 Different criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the less toxic trivalent form.

TABLE 6-25. ANNUAL URBAN RUNOFF LOADS KG/HA/YEAR

Constituent	Site Mean Con.mg/l	Residential	Commercial	All Urban
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
Total P	0.42	1.3	3.4	1.5
Sol. P	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NO_{2+3}-N	0.86	2.6	7.0	3.6
Tot. Cu	0.043	0.13	0.35	0.15
Tot. Pb	0.182	0.55	1.48	0.65
Tot. Zn	0.202	0.62	1.64	0.72

NOTE. Assumes 40 inches/year rainfall as a long-term average.

or lower rainfall, these load estimates must be adjusted. The results presented earlier suggest that pollutant concentrations are not sensitive to runoff volume; however, total loads (the product of concentration and volume) are strongly influenced by the volume of runoff. For estimates using equivalent site conditions (Rv), loads for areas with other rainfall amounts are obtained by factoring by the ratio of local rainfall volume to the 40 inch volume used for the table. Planners who believe that the average annual runoff coefficients in their local areas are substantially different from those used in the table can make similar adjustments.

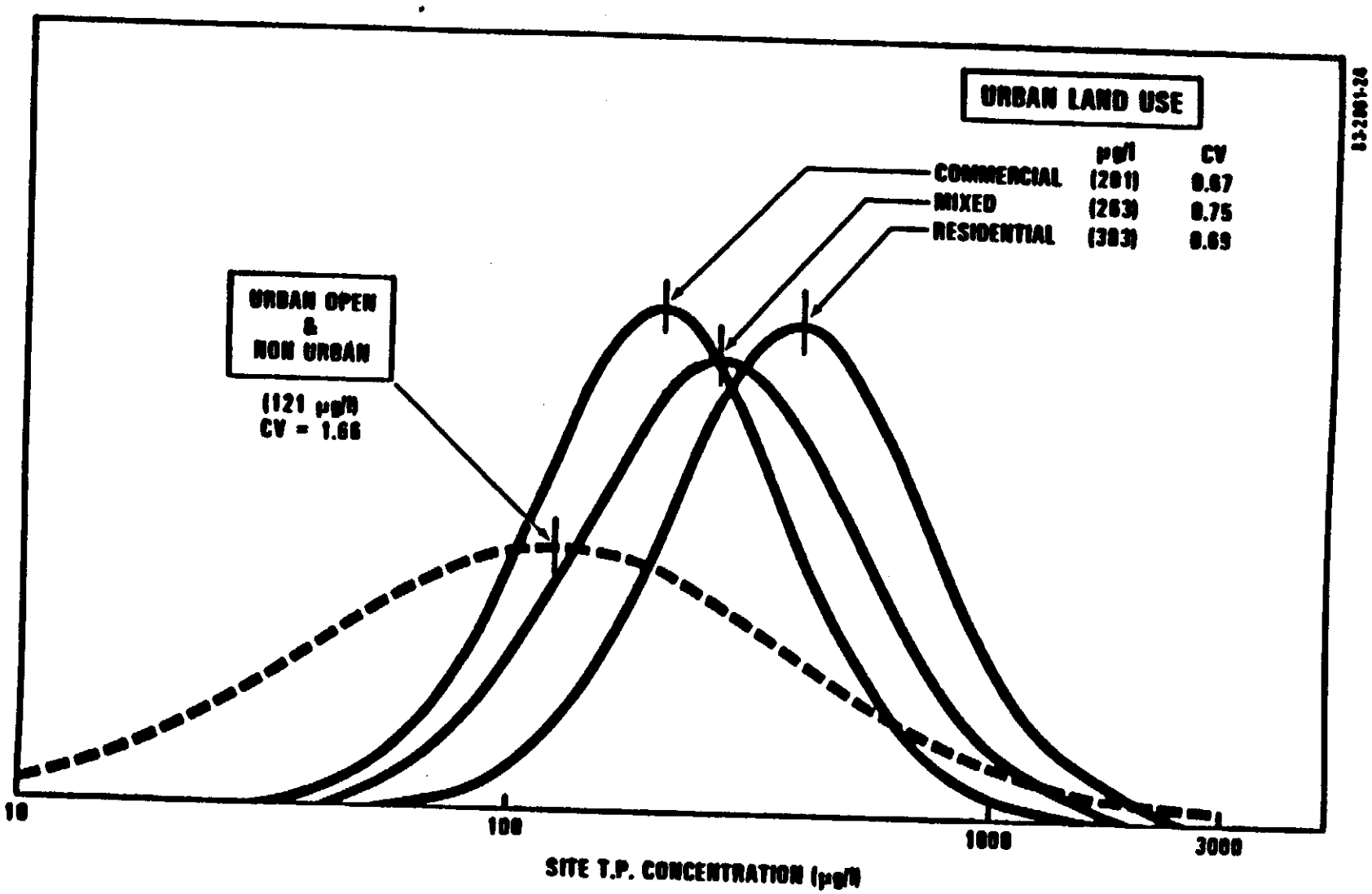


Figure 6-18. Site Median Total P EMC Probability Density Functions for Different Land Uses

APPENDIX 13
POTENTIAL GROUNDWATER CONTAMINATION FROM INTENTIONAL AND NONINTENTIONAL STORMWATER INFILTRATION

Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration

Dr. Robert Pitt, Shirley Clark, and Keith Palmer
Dept. of Civil and Environmental Engineering, University of Alabama at Birmingham

The following report of research was summarized from EPA/600/SR-94/051, May 1994. Studies were conducted in the first year of a three-year cooperative agreement to identify and control stormwater toxicants. The report discusses potential groundwater problems associated with stormwater toxicants, and how conventional stormwater control practices can reduce such problems.

Sources of Pollutants

High bacteria populations have been found in sheetflow samples from sidewalks, roads, and some bare ground (collected from locations where dogs would most likely be "walked"). Tables 1 and 2 summarize toxicant concentrations and likely sources identified during an earlier phase of research. The detection frequencies for the heavy metals are all close to 100% for all source areas, and the detection frequencies for the organics listed ranged from about 10% to 25%. Vehicle service areas had the greatest abundance of observed organics.

Table 1. Concentrations of Heavy Metals in Observed Areas (µg/L)

Toxicant	Highest Median		Highest Observed	
Cadmium	Vehicle service area runoff	8	Street runoff	220
Chromium	Landscaped area runoff	100	Roof runoff	810
Copper	Urban receiving water	160	Street runoff	1250
Lead	CSO	75	Storage area runoff	330
Nickel	Parking area runoff	40	Landscaped area runoff	130
Zinc	Roof runoff	100	Roof runoff	1580

Table 2. Maximum Concentrations of Toxic Organics from Observed Sources

Toxicant	Maximum, µg/L	Detection Frequency, %	Significant Sources
Benzo(a)anthracene	60	12	Gasoline, wood preservative
Benzo(b)fluoranthene	226	17	Gasoline, motor oils
Benzo(k)fluoranthene	221	17	Gasoline, bitumen, oils
Benzo(a)pyrene	300	17	Asphalt, gasoline, oils
Fluoranthene	128	23	Oils, gasoline, wood preservative
Naphthalene	298	13	Coal tar, gasoline, insecticides
Phenanthrene	89	10	Oils, gasoline, coal tar
Pyrene	102	19	Oils, gasoline, bitumen, coal tar, wood preservative
Chlordane	2.2	13	Insecticide
Butyl benzyl phthalate	128	12	Plasticizer
Bis(2-chloroethyl)ether	204	14	Fumigant, solvents, insecticides, paints, lacquers, varnishes
Bis(2-chloroisopropyl)ether	217	14	Pesticide manufacturing
1,3-Dichlorobenzene	120	23	Pesticide manufacturing

Nutrients

Nitrates are one of the most frequently encoun tered contaminants in urban groundwater. Nitrat leachs from fertilizers and affects groundwaters unde golf courses, parks, and lawns. Leaching of nitrate commonly occurs during the cool, wet seasons whe denitrification and ammonia volatilization and microbi nitrogen immobilization and plant uptake are reduce Nitrate is highly soluble and stays in solution in perco lation water. If nitrogen leaves the root zone withou being used by plants, it can reach the groundwater.

Pesticides

Pesticides found in urban groundwaters includ 2,4-D, 2,4,5-T, atrazine, chlordane, diazinon, ethio malathion, methyl trithion, silvex, and simazine. Fung cides and nematocides must be mobile to reach the ta get pest, and hence, they generally have the highe groundwater contamination potential. The greatest pes ticide mobility occurs in areas with coarse-grained c sandy soils without a hardpan layer, and with soils th have a low clay and organic matter content and hig permeability. The slower moving pesticides that bette sorb to soils are recommended for use in such area These include the fungicides iprodione and triadimefor the insecticides isofenphos and chlorpyrifos, and th herbicide glyphosate. Pesticides decompose in soil an water, but the total decomposition time can range fro days to years. Literature half-lives for pesticide generally apply to surface soils and do not account fo reduced microbial activity deep in the vadose zone.

Other Organics

The most commonly occurring organic compound found in urban groundwaters include phthalate este (especially bis(2-ethylhexyl)phthalate) and phenoli compounds. Other, more rare organics include the vo atiles: benzene, chloroform, methylene chloride, tr chloroethylene, tetrachloroethylene, toluene, and xy lene. Polyaromatic hydrocarbons (PAHs) (especial benzo(a)anthracene, chrysene, anthracene, and benz (b)fluoroanthenene) have also been found in ground waters near industrial sites. Groundwater contamina tion from organics, like other pollutants, occurs mor readily in areas with sandy soils and where the wate table is near the land surface. Organics can be re moved from the soil and recharge water by volatil zation, sorption, and degradation, to varying degrees.

Microorganisms

Viruses have been detected in groundwater where stormwater recharge basins were located short distances above the aquifer. Enteric viruses are more resistant to environmental factors than are enteric bacteria because of their structure and very small size, and they exhibit longer survival times in natural waters. Enteroviruses can occur in potable and marine waters in the absence of fecal coliforms, and are more resistant to common disinfectants than bacteria.

Bacteria in soil is removed mainly by straining at the soil surface and through intergrain contacts, sedimentation, sorption by soil particles, and inactivation. Because their size is larger than viruses, most bacteria are retained near the soil surface because of this straining effect. In general, enteric bacteria survive in the soil between two and three months, although survival times up to five years have been documented.

Metals

The metals in stormwater presenting the most concern for groundwater pollution are aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. The majority of these metals (with the common exception of zinc) are, however, mostly associated with the particulate fractions and can be mostly removed by either sedimentation or filtration processes. In general, studies of recharge basins receiving large metal loads found that most of the heavy metals are removed either in the basin sediment or in the vadose zone. Dissolved metal ions are removed from stormwater during infiltration mostly by adsorption onto the near-surface particles in the vadose zone, and the particulate metals are filtered out at the soil surface. Studies at recharge basins found that lead, zinc, cadmium, and copper accumulated at the soil surface with little downward movement over many years.

Similarities in water quality between runoff water and groundwater have shown that there is significant downward movement of copper and iron in sandy and loamy soils. Arsenic, nickel, and lead, however, did not significantly move downward through the soil to the groundwater. The exception to this was some downward movement of lead with the percolation water in sandy soils beneath stormwater recharge basins. Zinc, which is more soluble than iron, has been found in higher concentrations in groundwater than iron. The order of attenuation in the vadose zone from infiltrating stormwater is: zinc (most mobile) > lead > cadmium > manganese > copper > iron > chromium > nickel > aluminum (least mobile).

Salts

Salt applications for winter traffic safety is a common practice in many northern areas, and the sodium and chloride, which are collected in the snowmelt, travel down through the vadose zone to the groundwater with little attenuation. Soil is not very effective at removing salts. Studies of depth of pollutant penetration in soil have shown that sulfate and potassium concentrations decrease with depth, whereas sodium, calcium, bicarbonate, and chloride concentrations increase with depth.

Table 3. Reported Filterable Fractions of Stormwater Toxicants from Source Areas.

Constituent	Filterable Fraction (%)
Cadmium	20 to 50
Chromium	<10
Copper	<20
Iron	Small amount
Lead	<20
Nickel	Small amount
Zinc	>50
Benzo(a)anthracene	None found in filtered fraction
Fluoranthene	65
Naphthalene	25
Phenanthrene	None found in filtered fraction
Pyrene	95
Chlordane	None found in filtered fraction
Butyl benzyl phthalate	Irregular
Bis (2-chloroethyl) ether	Irregular
Bis (2-chloroisopropyl) ether	None found in filtered fraction
1,3-Dichlorobenzene	75

Treatment of Stormwater

Table 3 summarizes the filterable fraction of toxicants found in runoff sheet flows from many urban areas during an earlier phase of this EPA-funded research. Pollutants that are mostly in filterable forms have a greater potential of affecting groundwater and are more difficult to control with the use of conventional stormwater control practices which mostly rely on sedimentation and filtration principles. Luckily, most of the toxic organics and metals are associated with the nonfilterable (suspended solids) fraction of the stormwater. Possible exceptions include zinc, fluoranthene, pyrene, and 1,3-dichlorobenzene, which may be mostly found in the filtered sample portions. Pollutants in dry-weather storm drainage flows, however, are not as readily controlled by sedimentation.

Detention ponds are probably the most common management practice for the control of stormwater runoff. If properly designed, constructed, and maintained, wet detention ponds can be very effective in controlling a wide range of pollutants. The monitoring performance of wet detention ponds indicates more than 90% removal for suspended solids, 70% for BOD_5 and COD, and about 60% to 95% for heavy metals. Other mechanisms available in some larger wet detention ponds include volatilization and photolysis. Biodegradation, biotransformation, and bioaccumulation (into plants and animals) may also occur in larger and open ponds.

Upland infiltration devices (such as infiltration trenches, porous pavements, percolation ponds, and grass roadside drainage swales) can safely deliver large fractions of the surface flows to groundwater, if carefully designed and located. Local conditions that can make stormwater infiltration inappropriate include steep slopes, slowly percolating soils, shallow groundwater, and nearby groundwater uses.

Grass filter strips may be quite effective in removing particulate pollutants from overland flows. The filtering effects of grasses, along with increased infiltration/recharge, reduce the particulate sediment load from urban landscaped areas. Grass swales can be used in place of curb and gutter drainages in most land uses, except possibly strip commercial and high density residential areas.

Sorption of pollutants to soils is probably the most significant fate mechanism of toxicants in biofiltration devices. Many of the devices also use sedimentation and filtration to remove the particulate forms of the pollutants from the water. Underground seepage drains and porous pavements offer little biological activity to reduce toxicants.

Results

Table 4 is a summary of pollutants found in stormwater that may cause groundwater contamination problems. Causes of concern include high mobility (low sorption potential) in the vadose zone, high abundance (high concentrations and high detection frequencies) in stormwater, and high soluble fractions (small fraction associated with particulates that would have little removal potential using conventional stormwater sedimentation controls) in the stormwater. The contamination potential is the lowest rating of the influencing factors.

This table is only appropriate for initial estimates of contamination potential because of the simplifying assumptions made, such as the worst case mobility conditions assumed (for sandy soils having low organic content). When the soil is clayey and has a high organic content, then most of the organic compounds would be less mobile than that shown. The abundance and filterable fraction information is generally applicable for warm weather stormwater runoff in residential and commercial areas. The pollutant concentrations and detection frequencies, however, would be greater for critical source areas (especially vehicle service areas) and critical land uses (especially manufacturing areas).

The stormwater pollutants of most concern include:

- Nutrients. Nitrate has a low to moderate potential for contaminating groundwater when both surface percolation and subsurface infiltration/injection are used because of its relatively low concentrations in most stormwaters. When the stormwater nitrate concentration is high, the groundwater contamination potential would likely also be high.
- Pesticides. Lindane and chlordane have moderate potentials contaminating groundwater when surface percolation (with no p treatment) or when subsurface injection (with minimal pretreatme are used. The groundwater contamination potentials for both these compounds would very likely be substantially reduced w adequate sedimentation pretreatment.
- Other Organics. 1,3-dichlorobenzene may have a high potential contaminating groundwater when subsurface infiltration/injecti (with minimal pretreatment) is used. It would, however, probat have a lower groundwater contamination potential for most surfa percolation practices because of its relatively strong sorption vadose zone soils. Both pyrene and fluoranthene would also ve likely have high groundwater contamination potentials for subsu face infiltration/injection practices, but lower contaminatic potentials for surface percolation practices because of their mo limited mobility through the unsaturated zone (vadose zone Others (including benzo(a)anthracene, bis (2-ethylhexyl) phthalat pentachlorophenol, and phenanthrene) may also have moderat groundwater contamination potentials when surface percolation wit no pretreatment, or subsurface injection/infiltration, is used. Thes compounds would have low groundwater contamination potential when surface infiltration is used with sedimentation pretreatment VOCs may also have high groundwater contamination potentials present in the stormwater (which is possible for some industrial an commercial facilities and vehicle service establishments).
- Pathogens. Enteroviruses very likely have high potentials fo contaminating groundwater when any percolation or subsurfac infiltration/injection practice is used, depending on their presence i stormwater (especially if contaminated with sanitary sewage). Other pathogens, including *Shigella*, *Pseudomonas aeruginosa*, and various protozoa, would also have high groundwater contamination potentials when subsurface infiltration/injection practices are used without disinfection. When disinfection by chlorine or ozone is used, then disinfection by-products such as trihalomethanes or ozonated bromides would have high groundwater contamination potentials.
- Heavy Metals. Nickel and zinc possibly have high potentials for contaminating groundwater when subsurface infiltration/injection is used. Chromium and lead would have moderate groundwater contamination potentials for subsurface infiltration/ injection practices. All metals would possibly have low groundwater contamination potentials when surface infiltration is used with sedimentation pretreatment.
- Salts. Chloride would very likely have a high potential for contaminating groundwater in northern areas where road salts are used for traffic safety, irrespective of the pretreatment, infiltration, or percolation practices used.

Pesticides have been mostly found in urban runoff from residential areas, especially in dry weather flows associated with landscaping irrigation runoff. The other organics, especially the volatiles, are mostly found in industrial areas. The phthalates are found in all areas. The PAHs are also found in runoff from all areas, but they are in higher concentrations and occur more frequently in industrial areas. Pathogens are most likely associated with sanitary sewage contamination of storm drainage systems, but several bacterial pathogens are commonly found in surface runoff in residential areas. Zinc is mostly found in roof runoff and other areas where galvanized metal comes into contact with rainwater. Salts are at their greatest concentrations in snowmelt and early spring runoff in northern areas.

Recommendations

The control of these compounds requires various approaches, including source area controls, end-of-pipe controls, and pollution prevention. With a reasonable degree of site-specific design considerations to compensate for soil characteristics, infiltration may be very

deffective in controlling both urban runoff quality and quantity problems. This strategy encourages infiltration of urban runoff to replace the natural infiltration capacity lost through urbanization and to use the natural filtering and sorption capacity of soils to remove pollutants; however, the potential for some types of urban runoff to contaminant groundwater through infiltration requires some restrictions. Infiltration of urban runoff having potentially high concentrations of pollutants that may pollute groundwater required adequate pretreatment or the diversion of these waters away from infiltration devices.

The following general guidelines for the infiltration of stormwater and other storm drainage effluent are recommended in the absence of comprehensive site-specific evaluations:

- Dry weather storm drainage effluent should be diverted from infiltration devices because of their probable high concentrations of soluble heavy metals, pesticides, and pathogenic microorganisms.
- Combined sewage overflows should be diverted from infiltration devices because of their poor water quality, especially their high pathogenic microorganism concentrations and high clogging potential.
- Snowmelt runoff should be diverted from infiltration devices because of its potential for having high concentrations of soluble salts.
- Runoff from manufacturing industrial areas should be diverted from infiltration devices because of its potential for having high concentrations of soluble toxicants.
- Construction site runoff must be diverted from stormwater infiltration devices (especially subsurface devices) because of its high suspended solids concentrations, which would quickly clog infiltration devices.
- Runoff from other critical source areas, such as vehicle service facilities and large parking areas, should at least receive adequate pretreatment to eliminate their groundwater contamination potential before infiltration.
- Runoff from residential areas (the largest component of urban runoff in most cities) is generally the least polluted urban runoff flow and should be considered for infiltration. Very little treatment of residential area stormwater runoff should be needed before infiltration, especially if surface infiltration is through the use of grass swales. When subsurface infiltration methods such as seepage drains, infiltration trenches, or dry wells are used, then some pretreatment may be needed. Pretreatment may be provided by using grass filter strips or other surface filtration devices.

Table 4. Potential of Stormwater Pollutants to Contaminate Groundwater.

Compounds	*Mobility (sandy/low organic soils)*	*Abundance in Stormwater*	*Fraction Filterable*	*Surface Infiltration and No Pretreatment*	*Surface Infiltration with Sedimentation*	*Subsurface Injection with Minimal Pretreatment*
Nutrients						
Nitrates	mobile	low/moderate	high	low/moderate	low/moderate	low/moderate
Pesticides						
2,4-D	mobile	low	likely low	low	low	low
γ-BHC (lindane)	intermediate	moderate	likely low	moderate	low	moderate
malathion	mobile	low	likely low	low	low	low
atrazine	mobile	low	likely low	low	low	low
chlordane	intermediate	moderate	very low	moderate	low	moderate
diazinon	mobile	low	likely low	low	low	low
Other Organics						
VOCs	mobile	low	very high	low	low	low
1,3-dichlorobenzene	low	high	high	low	low	high
anthracene	intermediate	low	moderate	low	low	low
benzo(a)anthracene	intermediate	moderate	very low	moderate	low	moderate
bis(2-ethylhexyl) phthalate	intermediate	moderate	likely low	moderate	low	moderate
butyl benzyl phthalate	low	low/moderate	moderate	low	low	low/moderate
fluoranthene	intermediate	high	high	moderate	moderate	high
fluorene	intermediate	low	likely low	low	low	low
naphthalene	low/intermediate	low	moderate	low	low	low
pentachlorophenol	intermediate	moderate	likely low	moderate	low	moderate
phenanthrene	intermediate	moderate	very low	moderate	low	moderate
pyrene	intermediate	high	high	moderate	moderate	high
Pathogens						
enteroviruses	mobile	likely present	high	high	high	high
Shigella	low/intermediate	likely present	moderate	low/moderate	low/moderate	high
Pseudomonas aeruginosa	low/intermediate	very high	moderate	low/moderate	low/moderate	high
proteus	low/intermediate	likely present	moderate	low/moderate	low/moderate	high
Heavy metals						
nickel	low	high	low	low	low	high
cadmium	low	low	moderate	low	low	low
chromium	intermediate/very low	moderate	very low	low/moderate	low	moderate
lead	very low	moderate	very low	low	low	moderate
zinc	low/very low	high	high	low	low	high
Salts						
chloride	mobile	seasonally high	high	high	high	high

DRAWINGS

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