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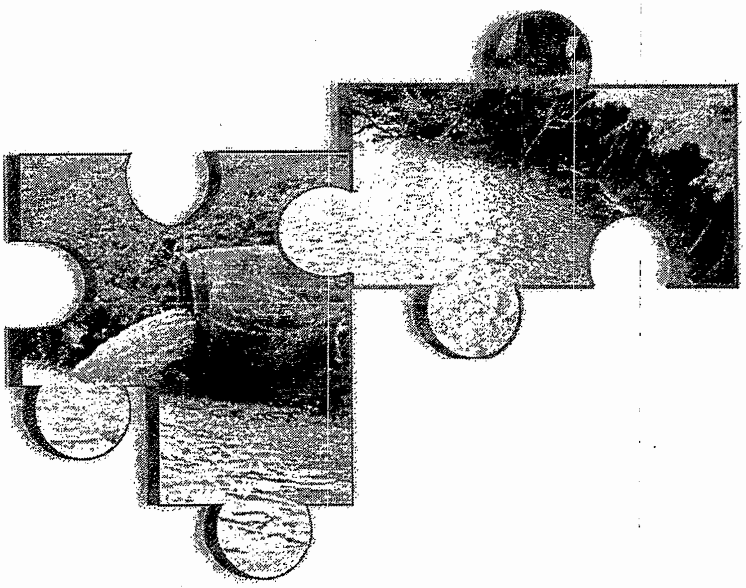
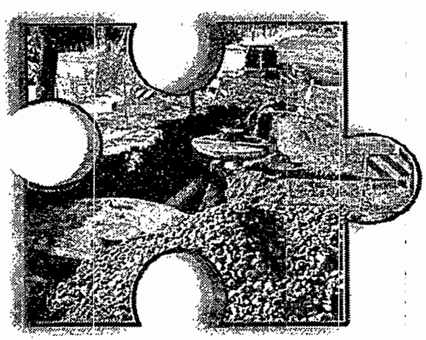
July 2000

National Conference on Tools for Urban Water Resource Management & Protection

Proceedings
Chicago, IL
February 7-10, 2000





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Technology Transfer and Support Division
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Notice

The views expressed in these Proceedings are those of the individual authors and do not necessarily reflect the views and policies of the U.S. Environmental Protection Agency (EPA). Scientists in EPA's Office of Research and Development have prepared the EPA sections, and those sections have been reviewed in accordance with EPA's peer and administrative review policies and approved for presentation and publication.

Preface

A wide array of effective water quality management and protection tools has been developed for urban environments, but implementation is hindered by a shortage of technology transfer opportunities. Held in Chicago, Illinois on February 8-10, 2000, the National ***Conference on Tools for Urban Water Resource Management and Protection*** was designed to facilitate the educational process and transfer state-of-the-art information to state, regional, and local urban water quality practitioners.

The Chicago Botanic Garden, which is owned by the Forest Preserve District of Cook County and managed by the Chicago Horticultural Society, was pleased to coordinate the Office of Wastewater Management and its Region 5 office, as well as the Northeastern Illinois Planning Commission. The conference was conducted in cooperation with the Water Environment Federation. Over 450 attendees participated, including representatives from Australia, Brazil, Canada, Chile, New Zealand, and Turkey.

The timing for this conference coincided well with the U.S. Environmental Protection Agency's release of the NPDES Storm Water Phase II Final Rule in October 1999. The conference provided participants with practical, applied information on the most effective tools and technologies for meeting these new NPDES permit requirements. Program topics were carefully chosen to reflect the Phase II Program's six priorities: public education, public involvement, detection and elimination of illicit discharges, construction site runoff control, post-construction storm water management, and pollution prevention for municipal operations.

Two special pre-conference workshops were held on February 7. ***Better Site Design and Storm Wafer*** Management Techniques ***for*** Phase ***II*** Communitiesexplored the benefits of alternative urban site design approaches, as well as new advances in storm water management to protect water resources. The workshop was led by staff from the Center for Watershed Protection. The second pre-conference workshop, ***Introduction to Urban TMDLs***, examined current and pending requirements for total maximum daily load (TMDL) programs. Instructors for this workshop were staff from Tetra Tech, Inc. Each of the workshops attracted over 135 participants.

This Conference Proceedings includes many of the papers presented during the conference. All papers included were peer reviewed. Additional copies, in either paper or CD-ROM format, are available free of charge from the U.S. Environmental Protection Agency, telephone 800/490-9198, or visit the web site <http://www.epa.gov/ttbnrmrl/>.

Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Contents

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Introduction

Stormwater runoff from urban and urbanizing areas is widely recognized as a major cause of water pollution in the United States. The impacts of stormwater runoff are threefold: (1) chemically, contaminants deposited on the land are carried by runoff and infiltration to surface and groundwater; (2) physically, increases in impervious surfaces raise runoff rates which, in turn, increase mass pollutant loadings and contribute to erosion and sedimentation; and (3) biologically, the combined chemical and physical alterations of watershed systems degrade aquatic habitat. Research over the past 20 years consistently shows a strong correlation between the imperviousness of a drainage basin and the health of its receiving waters, with stream health decreasing with increasing impervious coverage of the watershed.' The U.S. Environmental Protection Agency cites urban runoff as the second leading cause of impairment to estuaries and the fourth leading cause of impairment to lakes.* Increased runoff rates, and the erosion and sedimentation associated with new development and construction, also are significant sources of pollution. In the United States, there are an estimated 522,000 construction "starts" each year, with construction activities disturbing an estimated 5 million acres of land annually.[3]

Connecticut communities, like those in many urbanized states, are confronted with meeting nonpoint source management needs that often conflict with traditional subdivision regulations and construction standards. The challenge of meeting publicsafetyand maintenance requirements in an environmentally sensitive manner is not currently being met, as evidenced by continued water quality impairments associated with new development. Can impervious surfaces be reduced, and curbing and storm drains be eliminated in a way that will not raise objections from municipal boards and commissions? Will homeowners accept cluster housing, natural landscaping, and "greener" home and yard maintenance practices? Most important, will those modifications make a difference in the quality and quantity of nonpoint source runoff under widespread application? Answering these and related questions is the objective of the Jordan Cove Urban Watershed National Monitoring Project.

Project Overview

The primary purpose of the Jordan Cove project is to compare differences in runoff quantity and quality emanating from traditional and "environmentally sensitive" development sites. The 18-acre "Glen Brook Green" subdivision, located in the southeastern Connecticut town of Waterford, is being constructed and monitored to make this comparison. The subdivision is split into two distinct "neighborhoods": one with building lots arranged in a traditional R-20 (half-acre) zoning pattern (Figure 1); the other, cluster housing with a variety of best management practices (BMPs) incorporated into the design (Figure 2).

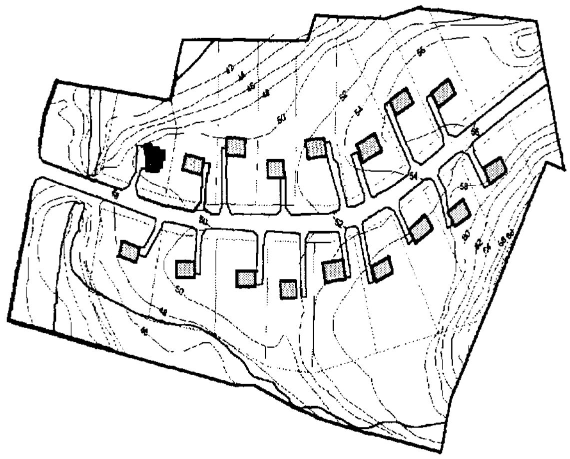

Figure 1. Glen Brook Green "Traditional" Neighborhood.

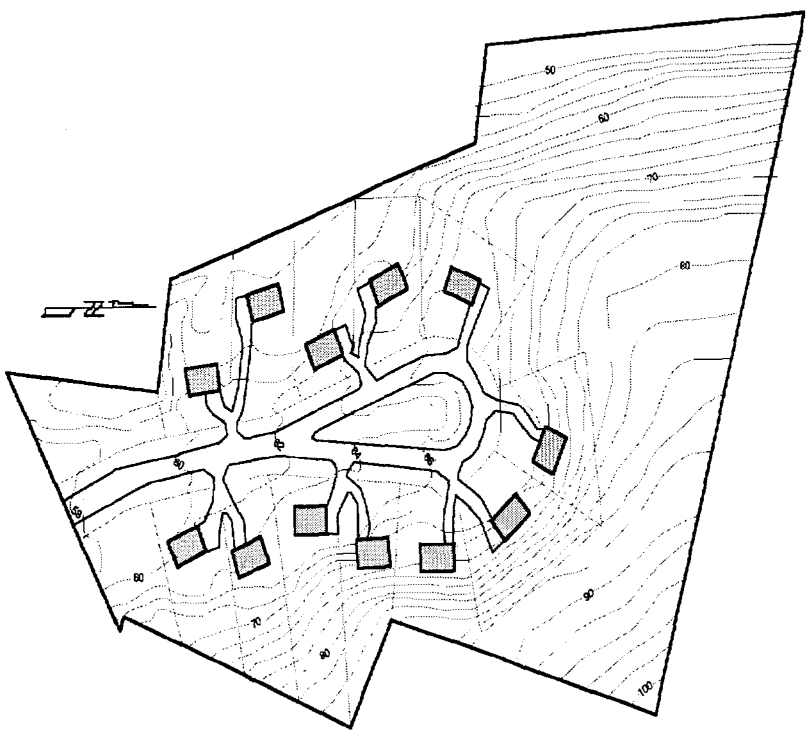

Figure 2. Glen Brook Green "BMP" Neighborhood.

Stormwater runoff from the traditional section is collected by curbs and catch basins, then piped through astormwater treatment system before entering Nevins Brook, a tributary of Jordan Brook and, ultimately, Jordan Cove and Long Island Sound. Homeowners will not be subjected to any enhanced environmental education, or restrictions on how they manage their properties.

The BMP neighborhood will feature grass swales; roof leader "rain gardens;" shared, permeable driveways; small building "foot-prints;"deed restrictions on increasing impervious surfaces; "low-mow," "no-mow," and conservationzones; a narrower, permeable road surface (interlocking concrete pavement); and a vegetated infiltration basin, or bioretention area, located inside a "tear-drop" *cul* de sac. Several different driveway surfaces will be utilized, including interlocking concrete pavement, gravel, concrete tire strips, and permeable asphalt, and monitored for their relative runoff rates. Homeowners and town road maintenance crews will be encouraged to adopt pollution prevention techniques, including controlled fertilizer and pesticide application, pet waste management, street sweeping/vacuuming, and reduced use of deicing agents.

The BMP neighborhood is expected to generate less stormwater runoff and pollution. Monitoring conducted before, during and after construction will document actual results. The Jordan Cove project team comprises a true public/private partnership, with researchers and educators from the University of Connecticut; federal, state, and local government officials; private consulting firms; and the developer.

National Monitoring Program

The Jordan Cove Urban Watershed National Monitoring Project is funded, in part, through the Connecticut Department of Environmental Protection (CT DEP) by the U.S. Environmental Protection Agency's (EPA) Section 319 National Monitoring Program (NMP). It is one of 22 such projects nationwide. The Jordan Cove project is the only NMP project studying the effects of residential subdivision development on runoff quality and quantity, and of BMPs designed to mitigate those impacts.

The Section 319 NMP was established pursuant to section 319(l) of the federal Clean Water Act (Nonpoint Source Management Programs - Collection of Information). Section 319(l) states that EPA shall collect information and make available:

(1) Information concerning the costs and relative efficiencies of best management practices for reducing nonpoint source pollution.

(2) Data concerning the relationship between water quality and implementation of various management practices to control nonpoint sources of pollution.

The objectives of the Section 319 NMP are twofold:

(1) To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution.

(2) To improve our understanding of nonpoint source pollution.

To achieve these objectives, the NMP has selected watersheds across the country to be monitored over a 6-to 10-year period to evaluate how improved land management and the application of BMPs reduce water pollution. The results from these projects will be used to assist land use and natural resource managers by providing information on the relative effectiveness of BMPs to control nonpoint source pollution.

Site Selection

In 1993, nonpoint source program staff from EPA and CT DEP, and a University of Connecticut researcher began efforts to identify a site at which to conduct a nonpoint source monitoring project under the auspices of the NMP. Initial site selection involved three criteria: (1) an appropriate hydrologic setting, with distinct drainage patterns amenable to monitoring; (2) a willing land owner or developer who would allow l-1 ½ years of advance monitoring before beginning construction; and (3) a municipality willing to adopt innovative site planning and development strategies. Proximity to the coast was also considered as an important factor because of the need to reduce nonpoint source pollution loads to Long Island Sound and coastal waters in general.

CT DEP mailed letters soliciting interest to a number of municipalities recognized for either their progressive approach to land use planning and management, orforexperiencing high development rates. After positive responses from several municipalities, and numerous field visits, the "Glen Brook Green" site in Waterford was selected in May 1995. The 18-acre parcel was an active chicken farm, but its owner, who had grown up on the farm, was planning to develop it into a residential subdivision. The property owner wanted to develop the parcel in an environmentally-sound manner, was interested in the NMP solicitation, and was willing to be flexible with his construction schedule to facilitate monitoring.

The hydrology of the parcel featured two distinct drainage areas, an ideal setting for the proposed monitoring design. Poultry houses and several other buildings occupied the area that would become the traditional neighborhood and an old, partially mined gravel pit dominated the future BMP neighborhood. Soil tests determined that the chicken manure had not elevated nutrient levels significantly enough to bias the monitoring. The town of Waterford, and its planning officials, had a reputation as being progressive on land use issues and had served as one of the pilot communities for the University of Connecticut Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) project. Because waivers from Water-ford's subdivision regulations would be needed to build the BMP neighborhood, the town's cooperation was critical to the project's implementation.

Planning

Proceeding from a conceptual design to actual construction required a concentrated effort by the project team working together toward a common goal. Once an acceptable plan was agreed upon by the project team and committed to paper, the next step was gaining approval from Water-ford's conservation, and planning and zoning commissions. As is typical of New England town governments, both commissions paid close attention to planning decisions at a series of public meetings at which many development alternatives were reviewed. Volunteer commissioners and professional staff raised numerous concerns regarding the health, safety and general welfare of the town residents, and the social economic, environmental, and political viability of the proposed plan. Among their concerns were road widths for emergency access, road surface integrity for plowing and de-icing, traffic, drainage, sidewalks, parking, maintenance of common areas, and responsibility should BMPs fail. The rigorous review was enlightening to the project team and commissioners alike. As the ongoing dialogue between the various parties led to further planning details and innovative solutions to problems, enthusiasm and support for the project grew.

After a series of public meetings in late 1996 and early 1997, the project was approved by both commissions. Technical modifications of existing standards were handled in four ways: as waivers, special design/operation controls, mitigation, or discretionary actions. Table 1 lists each of these categories with associated comments and concerns expressed by Water-ford's professional staff and commissions. In the end, it was the willingness of all parties involved to work in concert, reaching compromises, that allowed this innovative project to advance to the construction phase.

It is a generally accepted axiom that resource-based site planning can help minimize increases in runoff and reduce the potential for erosion and sedimentation problems typically associated with new development. In this project, goals identified at the outset are helping to direct the choice of practices and strategies for site development toward those that will reduce adverse impacts on hydrology and water quality. These goals include: (1) reproducing pre-development hydrological conditions; (2) confining development and construction activities to the least critical areas; (3) fitting the development to the terrain; (4) preserving and utilizing the natural drainage system; and (5) creating a desirable living environment.

Table 1. Technical Modifications of Existing Development Standards.

Considerations	Traditional Design	BMP/Cluster Design	Comments
waivers needed	specified road surface materials	segmental concrete pavers (permeable)	must be approved by public works; costs more
	typical road width = 28 feet, reduced to 24 feet	reduced road width to 20 feet for travel lane	must be approved by public works, fire, and police
	curbs and storm drains required	no curbs; grassed swales and sheet flow off road	turf stone installed to maintain road edge integrity; costs less
	90 ft paved cul-de-sac radius	one way cul de sac design to reduce road width and turning radius	further reduction in width and less need for snow plowing
special design/ operational control	planning and zoning standards	bioretention "rain gardens"	retains roof runoff on-site
	home owner discretion	vegetative maintenance	reduces fertilizer use; costs less
	home owner discretion	pesticide management	reduces pesticide use: costs less
	home owner discretion	domestic animal management	reduces pathogen runoff
mitigation required	road runoff piped to storm sewer		need to manage storm water entering the site from adjacent public road
	creation of 13,400 sq ft wetland at subdivision entrance		required to mitigate filling of 5000 sq ft of wetlands within subdivision
discretionary actions	R-20 single-family zoning	cluster and zero setback from lot lines	allows more open space and natural landscaping
	open space not contiguous with all lots	open space layout	compact housing; natural landscaping
	a driveway for each home	combined driveways	reduces curb cuts and impervious surface; cost less

Monitoring Design

This study is utilizing the "paired-watershed" monitoring design, which requires a minimum of two watersheds (control and treatment) and two periods of study (calibration and treatment). This approach assumes that there is a quantifiable relationship between paired water quality data for the two watersheds, and that this relationship is valid until a major change is made in one of the watersheds. It does not require that the quality and quantity of runoff be statistically the same for the two watersheds, but that the relationship between the paired observations of water quality and quantity remains the same over time -- except for the influence of the land use changes in the treatment watershed.[4]

The control watershed accounts for annual and/or seasonal climate variations. During the calibration period, no changes in land use occur in the watersheds and paired water quality and quantity data are collected to develop a baseline. The paired data are used to develop regressions for the control and treatment watersheds. The treatment period begins when changes in land use occur in the treatment watershed. A new regression is developed following the treatment period. Analysis of variance (ANOVA) is used to test the significance of the regressions in each period. Analysis of covariance (ANCOVA) is used to test the differences between the two regression slopes and intercepts. The changes between periods are calculated based on a comparison of predicted values, using the calibration regression equation, and observed values during the treatment period.[5]

For the Jordan Cove project, the treatment period will occur in two phases: (1) during construction of the traditional and BMP neighborhoods; and (2) after construction when the BMPs are in effect. The paired-watershed approach is being used to measure the differences in water quality and quantity between the treatment areas (traditional and BMP neighborhoods) and the control area (a nearby 1 O-year old subdivision) caused by construction in the two treatment areas and the application of BMPs in the BMP neighborhood. Stormwater quality and quantity are measured at the outlets of each of the two treatment neighborhoods, and the control watershed (Figure 3). Water quality is measured by analyzing weekly flow-weighted composite samples for total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH,-N), and nitrate+nitrite nitrogen (NO,-N). Grab samples are analyzed for fecal coliform and BOD,. Monthly analyses are conducted for copper, lead, and zinc.

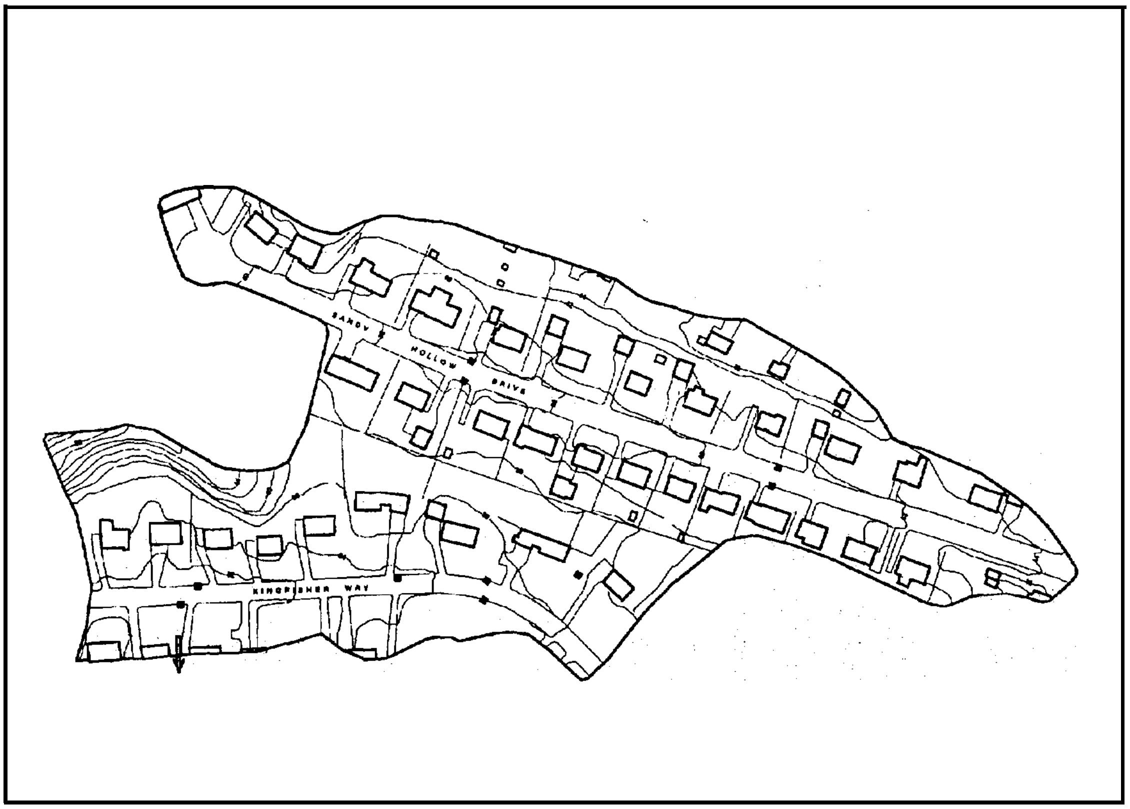

Figure 3. Existing residential (control) watershed.

The calibration period began in January 1996, to establish a baseline for future comparisons. Since the treatment period began in May 1998, runoff monitoring has focused on the effects of construction, and on the relative effectiveness of standard erosion and sediment control practices in the traditional neighborhood. When construction commences in the BMP neighborhood, the focus will be on the effects of construction and the relative effectiveness of enhanced erosion and sediment control practices (e.g., phased grading, stockpile seeding, open space vegetation, cross grading, and detention swales). Post-construction monitoring is scheduled to begin in 2001 and will continue for 3-5 years.

Supplemental monitoring will be conducted on selected BMPs, including different driveway surfaces and enhanced turf management in the BMP neighborhood, and a "state-of-the-art" stormwater treatment device in the traditional neighborhood. This information will be used to evaluate the effectiveness of these specific practices.

Monitoring Results

During the calibration period, 75 runoff events were sampled for the control watershed and 12 runoff events for the two treatment watersheds. In the treatment period to date, 21 and 20 events were sampled for each treatment watershed, respectively. Peak discharge values were obtained for nine paired events in the calibration period and 20 pairs for the treatment period. The total number of samples analyzed was less than the total number of flow observations because not all the samples contained a sufficient volume for analysis[6].

Sampling results to date, as presented in Table 2, indicate that construction of the traditional neighborhood is causing significant impacts on runoff quality and quantity, including observed increases in mean weekly flow volume (99%), runoff frequency (from 16% to 95%), and mean weekly peak discharge (79%).[7] The conversion of the watershed's topography from a "knoll" to a "bowl," combined with an increase in impervious surface, appears to have caused a significant change in hydrologic responses. Concentrations of NO,-N and Pb in runoff also increased. However, increases in the concentrations of sediment and sediment-associated nutrients, typical of construction sites, did not occur. In fact, TKN concentrations have declined during construction. It is believed that erosion and sediment controls are responsible for TSS concentrations remaining constant before and during construction*.

Table 2. Summary of means and percent increases of flow, Q_p, nutrient and metal concentrations for the control and traditional watershed in the calibration and treatment periods.

Calibration Period			Treatment Period			
				Traditional		
Parameter	**Control**	**Traditional**	**Control**	**Observed**	**Predicted**	**% Change**
------(m^3/week)------						
Flow	113.84	0.14	107.76	1.94	0.02	99***
------(m^3/sec*week)------						
Qp	0.05	3.00E-04	0.04	1.00E-03	3.00E-04	79***
------(mg/L)------						
TSS	31	132	28	106	121	-15
NO_3-N	0.5	0.3	0.4	0.8	0.3	62**
NH_3	0.15	0.08	0.31	0.18	0.17	2
TKN	1.3	4.0	1.8	2.1	4.5	-113**
TP	0.159	1.009	0.127	0.481	0.758	-58
------(ug/L)------						
Cu	8	8	14	21	13	38
Pb	6	11	6	17	10	42*
Zn	58	65	79	126	98	22

* P value < 0.05
** P value < 0.01
*** P value < 0.001

Coinciding with the increases in pollutant concentration and flow, the mass export of NO,-N and Pb increased as well, as did the mass exports of TP, TSS, Cu, and Zn. These increases appear to be attributable to increased stormwater runoff volumes. The preliminary results from this study suggest that increased runoff, rather than erosion, is the cause of increased pollutant export from this construction site. Traditionally, erosion and sediment controls and stormwater management plans focus on the prevention of sediment and, occasionally, peak flow impacts on downstream areas. The preservation of pre-development hydrologic conditions within the watershed where construction is occurring is typically ignored.

Excess runoff, which is the driving force behind nonpoint source pollution, will transport pollutants into waterways and contribute to their degradation. Preliminary monitoring results demonstrate that erosion and sediment controls can reduce sediment and sediment-associated pollutants in construction site runoff. However, current erosion and sediment control practices do not address the increase in runoff from development sites. Consequently, these practices fail at reducing pollutant loads.[9]

Next Steps

By the end of 2000, this combination of traditional and "green" designs for residential subdivisions should be fully constructed. Monitoring of stormwater quality and quantity will be conducted for several years after build-out to determine the overall efficiency of the design. It should demonstrate that careful planning, landscaping, and use of vegetative BMPs can help protect and enhance the environment, while addressing other concerns that local planning and zoning commissions face. Lessons learned from this project have already been, and will continue to be, passed along to other communities through ongoing technical assistance and training programs administered by the CT DEP, the University of Connecticut Cooperative Extension System, and other agencies and organizations.

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7. Ibid.
8. Ibid.
9. Ibid.

Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin, 1994-95

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Abstract

Eutrophication is a common problem for lakes in agricultural and urban areas, such as Lakes Wingra and Mendota in Madison, Wisconsin. This report describes a study to estimate the sources of phosphorus, a major contributor to eutrophication, to Lakes Wingra and Mendota from two small urban residential drainage basins. The Monroe Basin empties into Lake Wingra, and the Harper Basin into Lake Mendota. Phosphorus data were collected from streets, lawns, roofs, driveways, and parking lots (source areas) within these two basins and were used to estimate loads from each area. In addition to the samples collected from these source areas, flow-composite samples were collected at monitoring stations located at the watershed outfalls (storm sewers); discharge and rainfall also were measured. Resulting data were then used to calibrate the Source Loading and Management Model (SLAMM, version 6.3, copyright 1993, Pitt & Vorhees) for conditions in the city of Madison and determine within these basins which of the source areas are contributing the most phosphorus.

Water volumes in the calibrated model were calculated to within 23% and 24% of those measured at the outfalls of each of the basins. These water volumes were applied to the suspended-solids and phosphorus concentrations that were used to calibrate SLAMM for suspended-solids and phosphorus loads. Suspended-solids loads were calculated to be within 4% and 17%, total-phosphorus loads within 24% and 28%, and dissolved- phosphorus loads within 9% and 10% of those measured at the storm-sewer outfall at the Monroe and Harper basins, respectively.

Lawns and streets are the largest sources of total and dissolved phosphorus in the basins. Their combined contribution was approximately 80%, with lawns contributing more than the streets. Streets were the largest source of suspended solids.

Street-dirt samples were collected using industrial vacuum equipment. Leaves in these samples were separated out and the remaining sediment was sieved into >250 μm, 250-63 μm, 63-25 μm, <25 μm size fractions and were analyzed for total phosphorus. Approximately 75% of the sediment mass resides in the >250 μm size fractions. Less than 5% of the mass can be found in the particle sizes less than 63 μm. The >250 μm size fraction also contributed nearly 50% of the total-phosphorus mass. The leaf fraction contributed an additional 30%. In each particle size, approximately 25% of the total-phosphorus mass is derived from leaves or other vegetation.

Introduction

Eutrophication is a common problem for lakes in agricultural and urban areas, such as Lakes Wingra and Mendota in Madison, WI. Primary productivity in northern temperate lakes is most often limited by phosphorus (Schindler 1974; 1977). Urban runoff has been noted to contain high phosphorus concentrations (U.S. Environmental Protection Agency, 1983) that may be increasing the eutrophication. The focus of the study described in this report was to estimate the sources of phosphorus to Lakes Wingraand Mendotafrom two small urban residential watersheds in Madison, WI (Figure 1). This study was done in cooperation with the city of Madison and the Wisconsin Department of Natural Resources.

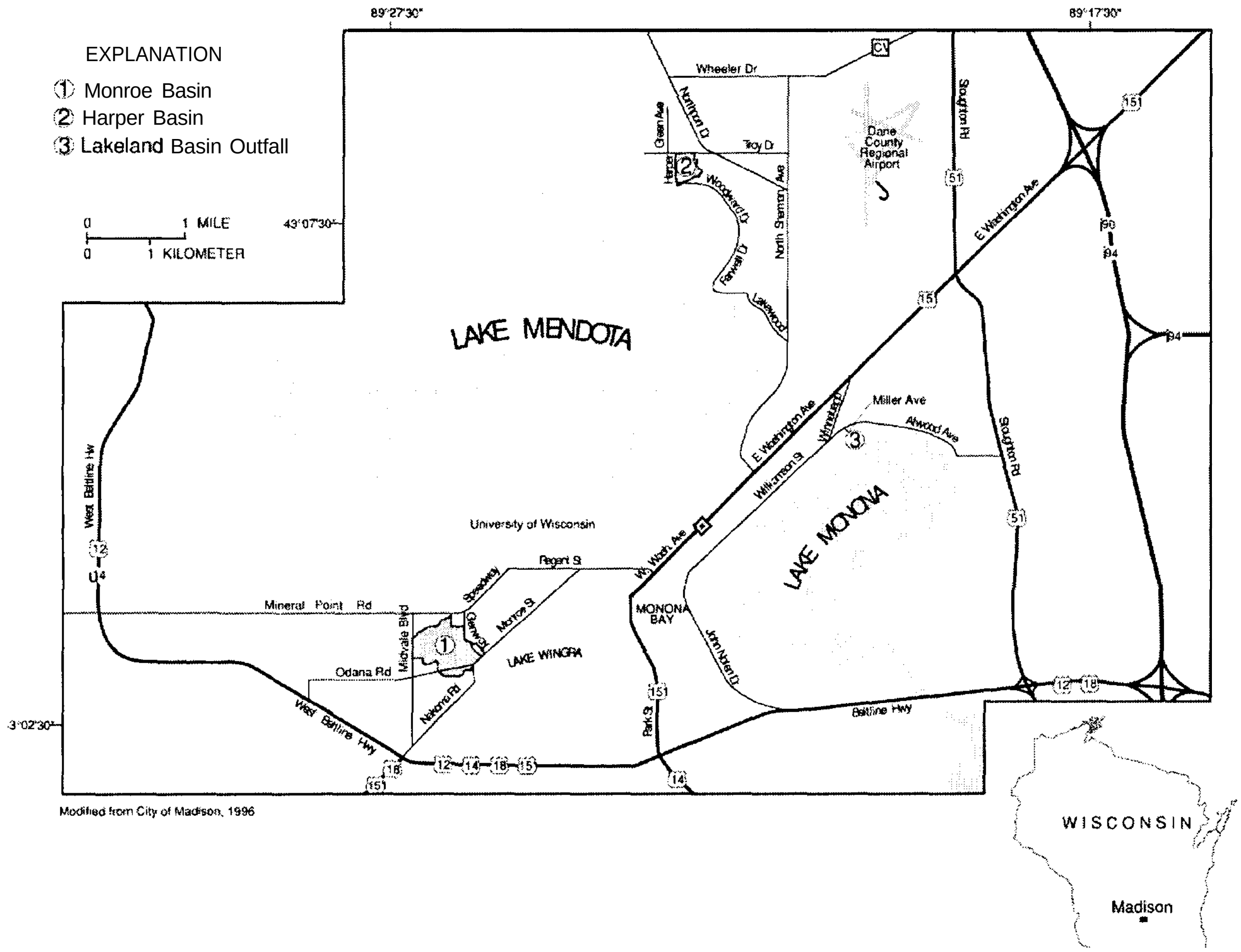

Figure 1. Lakes Wingra and Mendota in Madison, WI.

Lake Mendota and Lake Wingra are both part of the Wisconsin Department of Natural Resources (WDNR) Priority Watershed Program (Betz and others, 1997). State funding is available to help pay for management aimed at reducing the amounts of phosphorus and other pollutants discharged to the lakes. The goal of the Lake Mendota Priority Watershed Project is to reduce the frequency of nuisance algae blooms in the lake from one out of every two days to one out of every five days. To accomplish this goal, it is estimated that a 50% reduction is needed in the amount of phosphorus entering the lake. To help reach this target, the Nonpoint Source Control Plan for the Lake Mendota Priority Watershed Project (Betz and others, 1997) set an objective of reducing phosphorus loading to the lake by 20% from urban areas. The remaining 30% reduction is intended to come from rural phosphorus management.

For this study, phosphorus data were collected from five source areas-streets, lawns, roofs, driveways, and parking lots-within the two drainage basins from urban residential and commercial areas to estimate loads from each source area (Table 1). Resulting data were used to calibrate the Source Loading and Management Model (SLAMM, version 6.3, copyright 1993, Pitt & Vorhees) for conditions in the city of Madison and determine which source areas are contributing the most phosphorus within these basins. The city is planning to use SLAMM to target specific source areas for management efforts to meet the 20% phosphorus-reduction objective of the priority watershed project and to meet requirements of its Wisconsin Pollutant Discharge Elimination System stormwater permit.

Table 1. Land-use Characteristics of the Monroe Basin, 1994, and Harper Basin, 1995, in Madison, WI.
[--, source not present]

Source area	Monroe Basin Residential		Harper Basin Commercial		Harper Basin Residential	
	Acreage	Percent of basin	Acreage	Percent of basin	Acreage	Percent of basin
Lawn	**119.8**	**51.5**	--	--	23.6	57.4
Roof	26.5	11.4	2.3	1.0	5.4	13.2
Street	30.5	13.1	1.6	.7	5.3	13.0
Woodlot	--	--	--	--	3.0	7.3
Driveway	10.6	4.6	--	--	2.1	5.1
Park land	19.3	8.3	--	--	.7	1.7
Sidewalk	12.5	5.4	--	--	.7	1.7
Parking lot	.4	.2	3.4	1.5	.3	.7
Railroad bed	5.3	2.3	--	--	--	--
Total	224.9	96.8	7.3	3.2	41.1	100

Stormwater runoff samples from source areas and the basin outfall were collected from a medium-density residential watershed draining to Lake Wingra from May to November, 1994 and from a medium-density residential watershed draining to Lake Mendota from June to November 1995. These runoff samples were used to estimate the phosphorus and suspended-solids load that each of these source areas and basins contributes. In addition, a third basin, the Lakeland Basin that drains into Lake Monona, was monitored for lawn runoff in 1995. This basin, which encompasses an older section of Madison, was sampled in an attempt to determine whether any difference exists between this section of the city (which has older, smaller lawns) and other areas of the city.

Study-Area Description

The Monroe Basin, monitored during 1994, drains into Lake Wingra. The basin is 232.2 acres, of which 224.9 acres are residential and 7.3 acres are commercial (Figure 2). Lake Wingra has a surface area of 338.9 acres (1.37 km^2) and a drainage area of 3,889 acres (15.74 km*). About 75% of the Lake Wingra drainage basin is urbanized and about 25% is composed of forest, prairie, and marsh within the University of Wisconsin Arboretum (Oakes and others 1975).

The Harper Basin, monitored during 1995, drains into Lake Mendota. The Harper Basin is 41 .1 acres, all of which is residential land use (Figure 2). Lake Mendota has a surface area of 9,859 acres (39.9 km^2) and has a drainage area of 138,823 acres (561.8 km^2) (Lathrop and others, 1992). Approximately 20% of the Lake Mendota drainage area is urban, 57% is agricultural, and the remaining 23% is grassland/woodland/marsh/open-water area (Betz and others, 1997). The Lakeland Basin is approximately 3 miles southeast of the Harper Basin.

In addition to the samples collected from source areas, a monitoring station was located at each basin storm-sewer outfall to collect flow-composite samples and to monitor discharge and rainfall. The total rainfall amounts for the months of June through October 1994 at Monroe and July through October 1995 at Harper were 9.24 and 10.67 in., respectively. These amounts are 64% and 71% of the average from 1961 to 1990 (Brian Hahn, National Weather Service, oral communication, 1997).

Acknowledgments

We thank all of the volunteers that allowed us to install our sampling equipment in their yards, the City of Madison Engineering Division and Department of Public Health for their efforts in making this study possible, Jeff Beck of the USGS for his exceptional field efforts, and Holly Ray and Dr. Bob Pitt at the University of Alabama at Birmingham for their work analyzing the street-dirt samples. Also, we thank Mary Anne Lowndes of the WDNR and

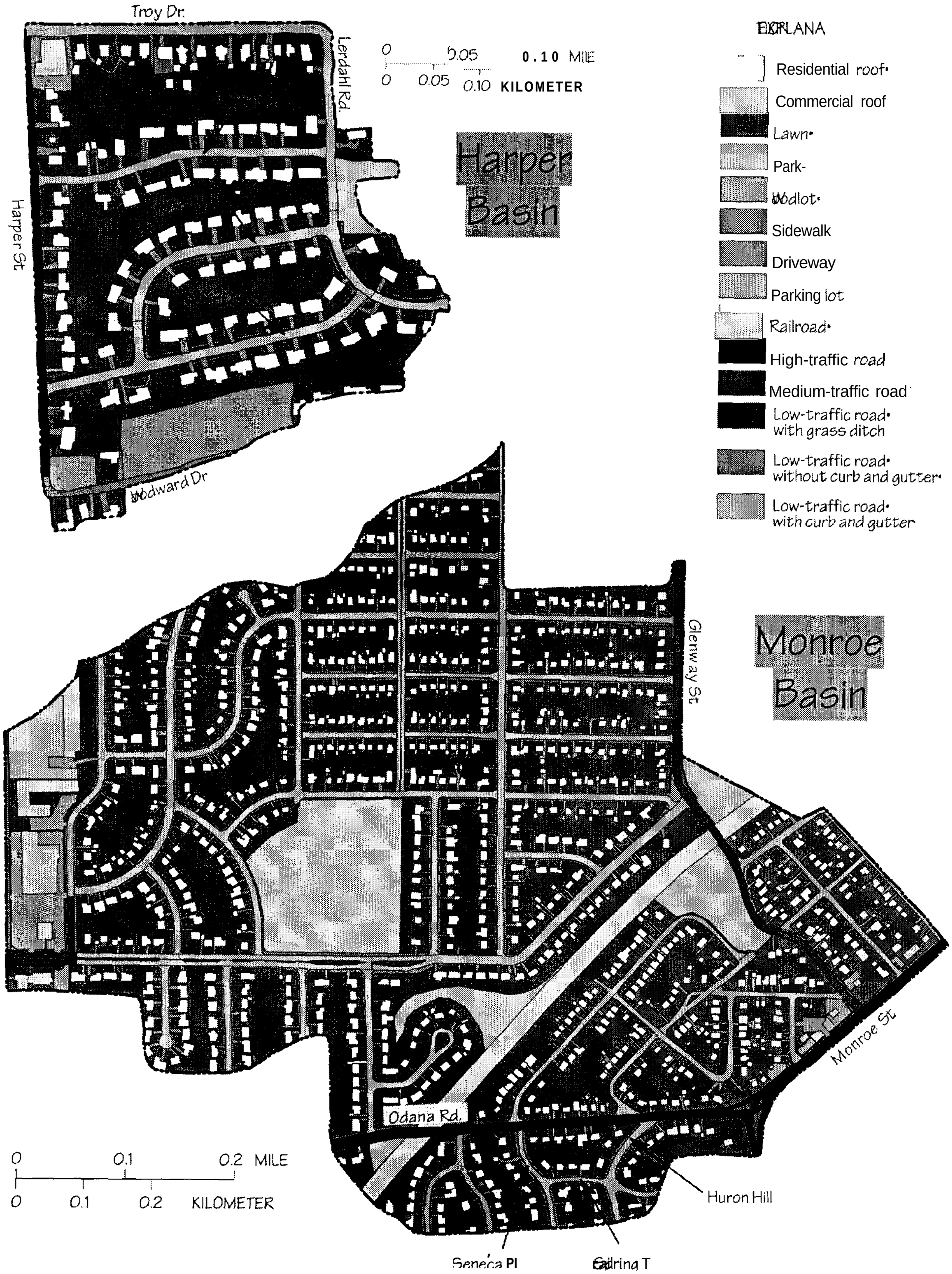

Figure 2. Harper and Monroe Basins.

Steve Corsi of the USGS for insightful comments that have greatly improved the report. Lastly, we thank Gail Moede and Aaron Konkol at the USGS for their help with the report editing and preparation of illustrations.

Data-Collection Equipment and Methods

Runoff samples were collected from each source area by use of sampling equipment slightly modified from that described by Bannerman and others (1993). Brief descriptions of the sampling equipment follow.

Street samplers. The street samplers were grouted into the street approximately 5 ft from the curb (Figure 3). The sample bottle was covered with a 6-in. concave polycarbonate cap, set flush with the street surface, with a center drain hole. The bottle and cap were placed into a 6-in. diameter polyvinyl chloride (PVC) sleeve. Water flowed over the top of the cap and drained through the center hole into a collection bottle. The drain hole could be constricted by a set screw that controlled the flow rate into the sample bottle.

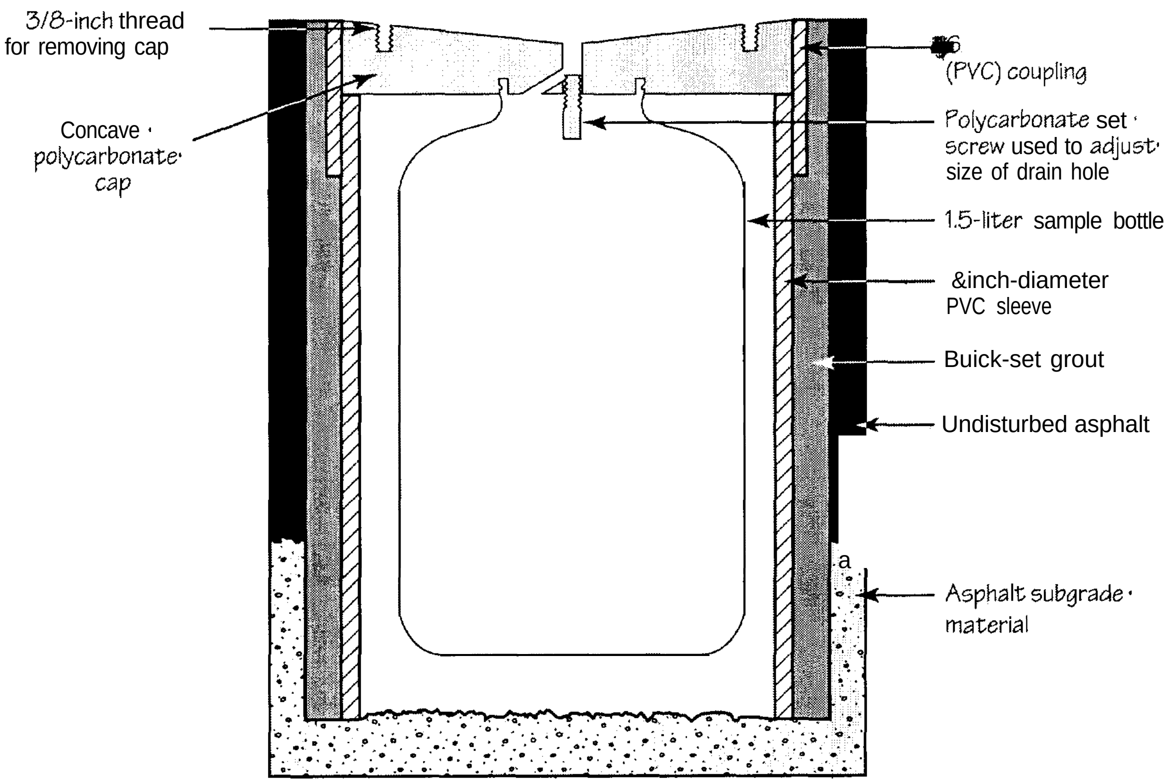

Figure 3. Schematic of street samplers.

Driveway samplers. Runoff water from driveways was diverted into a sampler by means of a flat piece of clear plastic, 1/4 in. high by 1 in. wide by 3 ft long, glued to the surface of the driveway. The sampler consisted of a 1.5-L glass bottle placed in a 10-in.-diameter protective PVC sleeve set into the ground next to the driveway. A 1/2-in.-diameter silicon tube carried the runoff through a plastic cap covering the PVC sleeve and into the sampler. During the 1994 field season, the tubing emptied directly into the sample bottle, causing several sample bottles to overfill. To alleviate this problem, in 1995, the tube emptied onto a polycarbonate cap like those used with the street samplers, so that the volume of water entering the sample bottle could be controlled.

Lawn samplers. Lawn sample bottles received runoff through two 5-ft pieces of 1/2-in.-diameter PVC pipe placed flush with the surface of the ground, on a sloping surface, with an angle of about 150 degrees between the two pipes (Figure 4). Runoff entered the pipes through two slits cut the entire length of pipe. Each pipe was wrapped with fiberglass

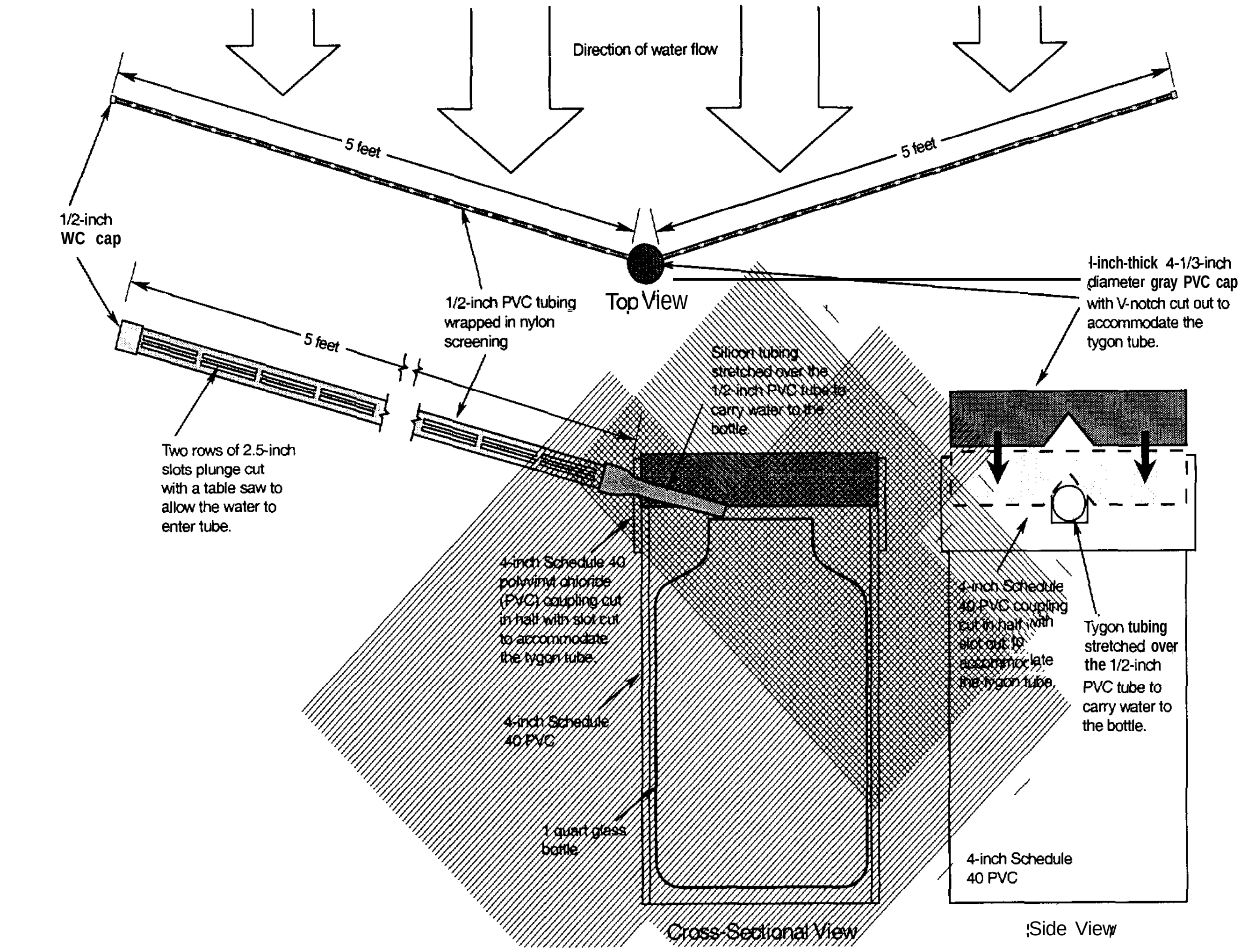

Figure 4. Schematic of lawn samplers.

screen to prevent insects and large debris from entering. Wooden clothespins with small pieces of nylon rope held the pipes in place. Water from the pipes flowed into a sampler through a notched cap. The sampler was a 1- qt glass bottle placed in a 4-in.-diameter protective PVC sleeve. The cap had a notch to accommodate silicon tubing, which ran from the end of the PVC collector pipes to the sample bottle.

Roof samplers. Roof samplers were designed to divert a small portion of the water in the gutter downspout to a sample bottle. A 1/4-in.-diameter vinyl tube was attached to the inside of the downspout by means of plastic wire ties. Each tube went into a 1.5-L glass sample bottle that was placed in a covered 10-in.-diameter protective PVC sleeve. Because of problems with overfilled sample bottles, the design was changed in the same manner as the driveway samplers so that the volume of water entering the sample bottle could be controlled.

Parking Lot sampler. The parking lot sampler collected runoff entering a storm-sewer inlet grate. A small portion of the inlet flow was diverted to a sample bottle by means of a 6-in. trough made of 1/2-in.-diameter PVC pipe cut length-wise and held in place with stainless steel hose clamps attached to the inlet grating. Water drained from the trough through a tube to a 2.5-gal glass sample bottle hanging from the inlet grate. No samples were collected from parking lots during 1995.

Basin storm-sewer outfall samplers. An automated sampling station was placed at the storm-sewer outfall of both the Monroe and Harper Basins. In 1994, water level in the basin storm- sewer outfall pipe was measured with a pressure transducer as water drained into a detention pond. Velocity was measured with an electromagnetic velocity meter. In 1995, stormwater-runoff volumes were computed using a modified Palmer-Bowlus flume design (Kilpatrick and others, 1985). The water level was measured one pipe diameter (36 in.) upstream from the entrance to the flume using a pressure transducer connected to a nitrogen bubble system. This water level was used in the following equation to calculate the total discharge through the flume:

$$Q = a[H_a / D]^b D^{2.5},$$

where

Q is discharge, in cubic feet per second,
a is a constant, 3.685,
b is a constant, 1.868,
H_a is the water level above the upstream lip of the flume, at a distance of one pipe diameter upstream from the flume entrance, in feet, and
D is pipe diameter, in feet.

Flow-composite water quality samples were collected using programmable, refrigerated automaticsamplerswith 3/8-in.-diameter Teflon-lined sample tubing. Rainfall was measured using a tipping-bucket rain gage and was recorded by a digital data logger.

Stormwater Sample Collection and Processing Protocols

Sample bottles were placed in the source-area samplers as close to the start of each rain event as possible. As the bottles were being deployed, the sampling equipment was rinsed with deionized water to remove any accumulated surface dirt. Before the lawn sampler pipes were rinsed, they were cleaned with a small test tube brush. As soon as possible after runoff had stopped, the sample bottles were collected and the approximate volume of water in each bottle was recorded.

All the bottles from a given source area were composited by pouring water from each bottle into a 5-gal or l-gal stainless steel, Teflon-coated churn splitter modified from the type described in Ward and Harr (1990). The City of Madison Department of Public Health Laboratory analyzed a small subsample taken from the churn for suspended solids and phosphorus.

Street Dirt Collection and Analysis

In addition to stormwater-runoff samples, samples of street dirt were collected with a 9-gal wet-dry shop-vacuum using a 6-in.-wide wand. A section of the street was vacuumed from curb to curb, 10 times across each of 3 streets in the basin, similar to the technique described by Pitt (1979) and Bannerman (1983). Monroe Street, Glenway Street, and Seneca Place/Spring Trail/Huron Hill (the latter three are considered one residential street) were sampled during 1994 (Figure 2). Woodward Drive, Nova Way, and Luster Avenue were sampled during 1995. Woodward Drive did not have curbs, so the sample was collected by vacuuming between wooden 4-by 4-in. blocks placed at the edge of the asphalt on each side of the street. During the fall, leaves on the street would often plug the vacuum hose. To alleviate this problem, a 6-in. by 2-ft wooden frame was placed with the 6-in. side abutting the curb. Before vacuuming the inside of the frame, the leaves inside it were collected by hand and placed in the vacuum collection bag. Then the street was vacuumed in the normal manner.

The dirt samples were dried at 105°C, sieved into size fractions of >250 μm, 250-63 pm, 63- 25 pm, and <25 μm and weighed. The sieved samples were sent to the University of Alabama at Birmingham (UAB) for phosphorus analysis. In addition to total phosphorus, samples collected from the Monroe Basin were analyzed for percentage of vegetative material. Two independent methods were used to determine the percentage of vegetative material: thermal chromatography and microscopic examination. In thermal chromatography, dirt samples were placed in ovens at increasing temperatures and the mass that was lost to incineration was determined after each increase in temperature. The mass loss was compared to the standard temperatures where various substances like leaves, rubber, and paper burned off. The sample mass lost at the temperature range corresponding to the leaf standards was assumed to be vegetation. In microscopic examination, samples of the dirt were compared to microscopic pictures of vegetation. More details of these methods can be found in Ray (1997).

Sources of Phosphorus

Measured Concentrations in Runoff from Source Areas

A total of 25 runoff events were monitored at each basin. Runoff samples were collected from May to November of 1994 at Monroe and from June to November of 1995 at Harper and Lakeland. Driveway samples collected from the Monroe Basin were excluded because of problems with the sample bottle overfilling (discussed in the methods section). Summary statistics are listed in Table 2.

Table 2. Concentrations for Suspended Solids, Total Phosphorus, and Dissolved Phosphorus at the Monroe Basin and Harper Basin, 1994-95
[--, concentrations were not used because of problems with the samplers; -, source area not present in basin; mg/L, milligrams per liter]

Statistic	Source area							
	Lawns	Feeder Street	Collector street	Arterial street	Driveways	Parking lots	Pitched roofs	Flat roofs
MONROE BASIN								
Suspended solids (mg/L)								
Geometric mean	59	68	51	65	--	51	15	18
Coeff. of variation	.55	1.17	.97	.92	--	1.27	.95	1.21
Mean	85	99	67	83	--	82	85	35
Median	75	60	46	64	--	44	18	20
Total phosphorus (mg/L)								
Geometric mean	0.79	0.40	0.22	0.18	--	0.10	0.07	0.13
Coeff. of variation	.62	1.24	1.23	1.15	--	1.04	.76	.96
Mean	1.03	.75	.36	.24	--	.14	.09	.2
Median	.99	.31	.16	.17	--	.09	.06	.12
Dissolved phosphorus (mg/L)								
Geometric mean	0.37	0.16	0.05	0.03	--	0.02	0.02	0.02
Coeff. of variation	.62	1.72	1.47	1.20	--	1.24	1.22	1.24
Mean	.52	.40	.14	.05	--	.04	.03	.04
Median	.61	.14	.04	.03	--	.02	.02	.02
HARPER BASIN								
Suspended solids (mg/L)								
Geometric mean	122	69			34		17	
Coeff. of variation	.37	.68			.93		.96	
Mean	132	98			57		25	
Median	154	88			31		17	
Total phosphorus (mg/L)								
Geometric mean	1.61	0.24			0.18		0.15	
Coeff. of variation	1.12	.75			.80		.68	
Mean	2.34	.31			.24		.19	
Median	1.54	.22			.20		.15	
Dissolved phosphorus (mg/L)								
Geometric mean	0.77	0.08			0.07		0.08	
Coeff. of variation	1.51	.98			1.0		.83	
Mean	1.54	.12			.11		.11	
Median	.81	.08			.07		.07	

The concentration data from the Monroe and Harper Basins seem to exhibit log-normal distributions that are consistent with urban-runoff concentration datacollected during the Nationwide Urban Runoff Project (U.S. Environmental Protection Agency, 1983). In such cases, the geometric mean is a better estimate of the central tendency than the arithmetic mean because the geometric mean gives less weight to extremes (Helsel, 1992). Several of the coefficients of variation in Table 2 have a value greaterthan 1, indicating substantial variability in concentrations within a source area.

The large variation seen in the source-area concentration data could cast doubt on the predictability of the data. For lawn runoff, the difference between geometric mean phosphorus concentrations from 1994 to 1995 was greater than a factor of 2; however, the lawn-runoff data collected from the Lakeland Basin are remarkably similar to data collected at Harper (Table 3), indicating that the variation in lawn-runoff phosphorus concentrations is not random. Primary sources of phosphorus, such as tree canopy, also could have a large effect on the source-area concentrations measured between basins. Figure 5 illustrates a trend between the concentration of phosphorus and the percentage of overhead tree canopy on streets for the Monroe and Harper Basins. Canopy in the Monroe Basin tends to be less than 35%, whereas the percentage of canopy in the Harper Basin ranges from 5 to 78%. Variation also could be caused by meteorological factors like rain depth, intensity, or inter-event period or by seasonal variables.

Roof runoff had the lowest geometric mean concentrations of suspended solids, and lawn runoff had the highest total and dissolved phosphorus concentrations in both the Monroe and Harper Basins (Figures 6 and 7). In addition, patterns in geometric mean concentrations between source areas within each basin were similar; however, their magnitudes were very different. The geometric mean concentration of phosphorus for low-traffic streets in the Monroe Basin were about twice those at the Harper Basin. Conversely, geometric mean phosphorus concentrations for lawn and roof runoff in the Harper Basin were more than twice as high as those in the Monroe Basin. The beginning of the sampling periods differed by one month between basins (Monroe Basin in May and Harper Basin in June), and this difference may have caused some of the variability.

Concentration results for suspended solids and phosphorus from earlier source-area studies in Madison, WI, Marquette, Ml, and Birmingham, AL (Bannerman and others, 1993; Steuer and others, 1997; Pitt and others, 1995), were compared to the concentration results from this study. Suspended-solids concentrations in street-runoff samples collected during the other studies were considerably higher than those in samples collected forthis study. Sandier soils are present in Marquette that could partially account for this difference. Furthermore, some of the same lawns in the Monroe Basin were monitored for phosphorus concentrations in the previous Madison study (Bannerman and others, 1993), and both the dissolved and total phosphorus geometric means calculated for that study were more than three times higher than those in 1994. Because phosphorus concentrations varied highly from Monroe and Harper Basins, did not closely agree with each other, and did not agree well with previous studies, the geometric mean of the combined data collected at Monroe and Harper Basins was used for the modeling phase of this study.

Table3. Rainfall Amountsand Intensities and Total-phosphorus Concentrations from Lawn-runoff Samples for Harperand Lakeland Basins, Madison, WI, 1995

	HARPER			LAKELAND		
Start of rain event (date)	**Rainfall** (inches)	**Intensity (in/hr)**	**Total-phosphorus concentration (mg/L)**	**Rainfall (inches)**	**Intensity (inhr)**	**Total-phosphorus concentration (mg/L)**
06/26/95	0.26	0.12	10.72	0.31	0.17	9.05
07/05/95	.36	.62	1.32	.10	.16	2.06
07/15/95	.50	.12	3.61	.80	.10	2.99
07/22/95	.79	.10	1.08	.80	.09	1.35
08/16/95	.61	.43	1.82	.55	.94	2.48
08/16/95	.38	.29	.60	.55	.49	.58
08/28/95	.80	.19	1.39	.67	.15	1.58
10/19/95	.32	.07	2.24	.33	.06	2.59

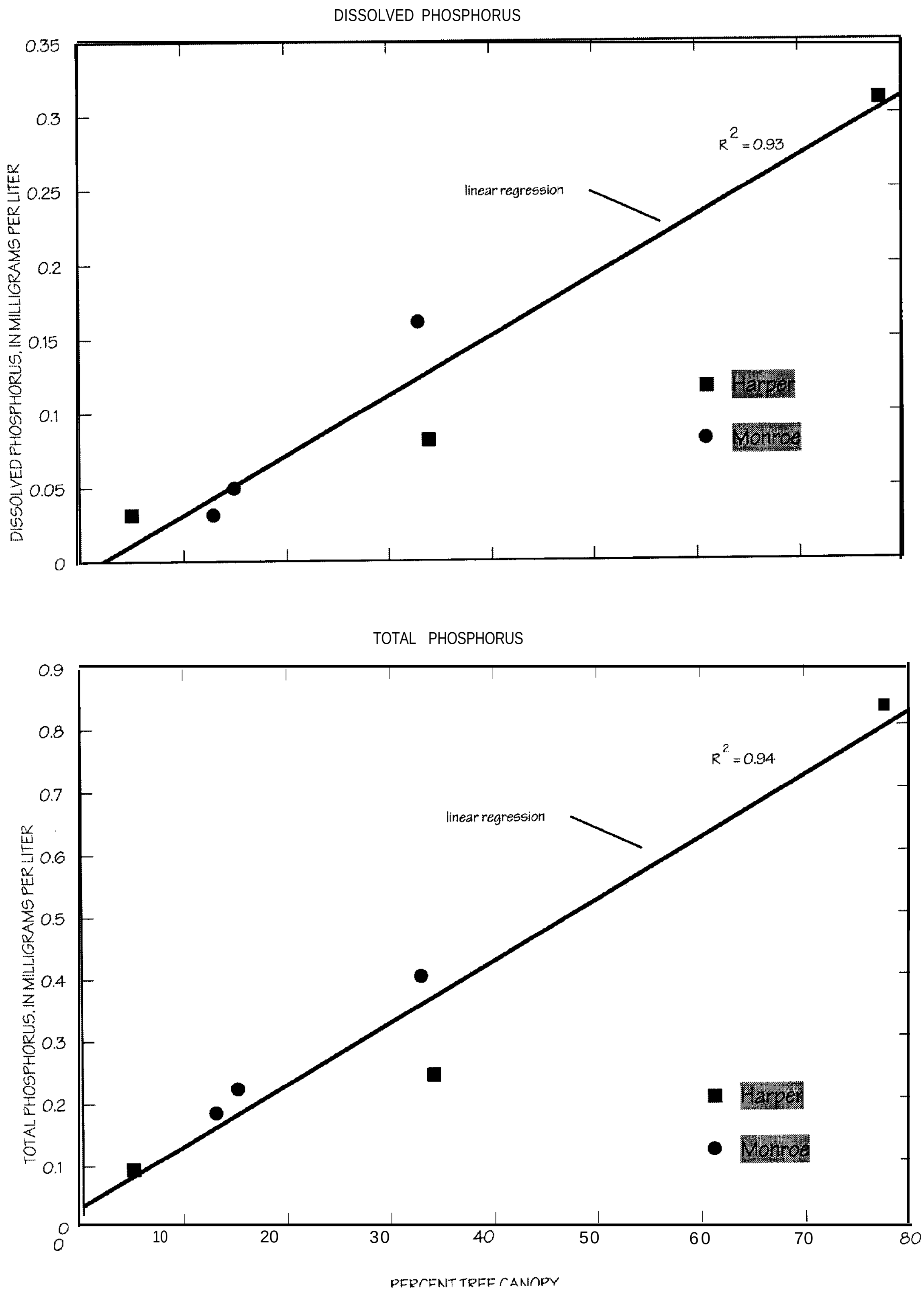

Figure 5. Trend between concentration of phosphorous and percentage of overhead tree canopy on streets for Monroe and Harper Basin.

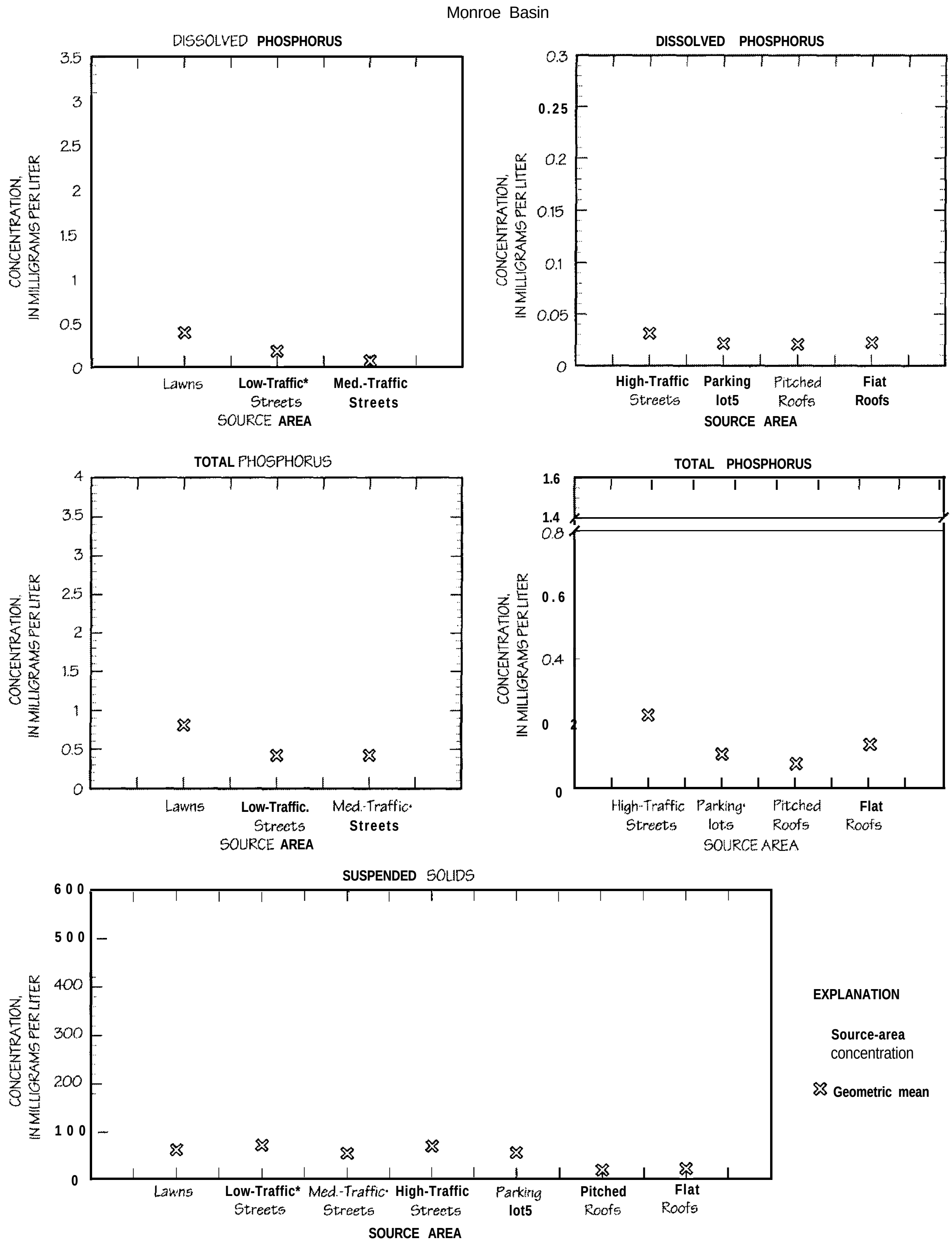

Figure 6. Dissolved phosphorous concentrations in Monroe Basin.

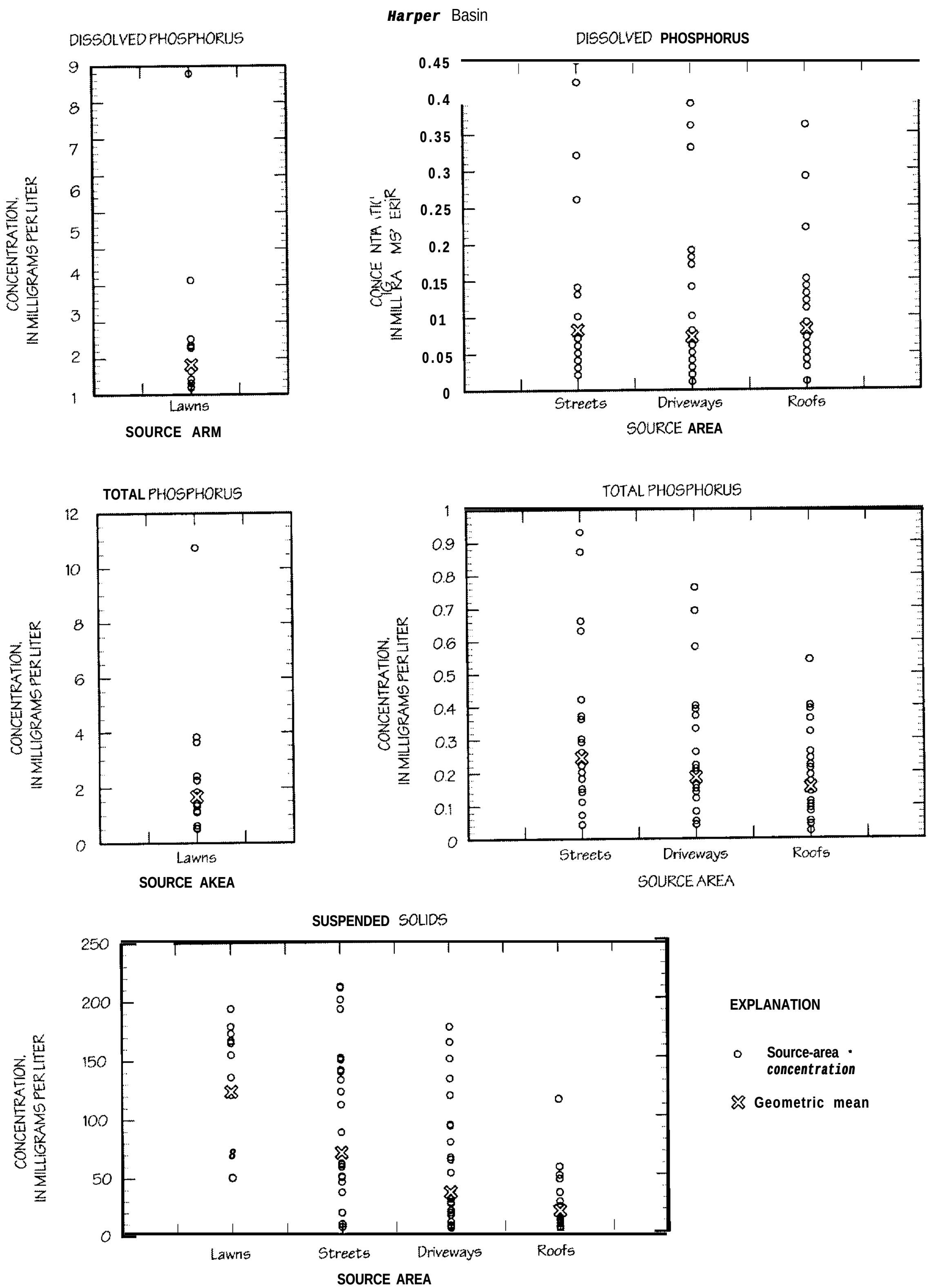

Figure 7. Dissolved phosphorous concentrations in Harper Basin

Calibration of the Source Loading and Management Model (SLAMM)

A concentration data base to simulate stormwater quality and theoretical runoff coefficients to simulate runoff volumes is used in the Source Loading and Management Model (SLAMM). Because large amounts of concentration data and runoff information were collected during this study, it was an opportunity to calibrate the model's concentration data base and improve the runoff coefficients with data collected from the Monroe and Harper Basins.

Calibrating SLAMM with concentration and water-volume data was a three-step process. First, the runoff volume generated by each source area was calibrated (a critical step because an accurate water volume is essential for estimating all pollutant loads). Second, sediment was calibrated because sediment concentrations and loads are used in SLAMM to estimate phosphorus loads. The final step was to calibrate the model for phosphorus concentrations.

A systematic procedure was used to calibrate suspended-solids and phosphorus concentrations in SLAMM. First, a mass-balance approach compared total measured loads from source areas summed over 25 events to the loads measured at the outfall. Monitored loads from source areas were calculated using SLAMM-generated water volumes. Individual source areas were not equipped to measure runoff volumes during an event. Therefore, the accuracy of source-area volumes, as assigned by SLAMM, was subject to agreement with the actual volumes measured at the outfall. If the sum of all source-area volumes closely matched what was measured at the outfall, the individual source-area volumes assigned by SLAMM were assumed to be correct. Second, source-area concentrations were adjusted to optimize the mass balance. SLAMM was adjusted after agreement between measured source-area and outfall loads was achieved.

Water-Volume Calibration

Water-runoff volume from each source area for each rain event is calculated with the model. These calculations are based on the amount of rainfall and a runoff coefficient developed for various rainfall depths for each source area. Source-area characteristics such as imperviousness, connectedness (amount of impervious area directly connected to the storm sewer), and infiltration rates on pervious areas were used to develop runoff coefficients (Pitt, 1987). The volumetric discharges for each source area are then summed for each event. The total runoff volume can be decreased in the model by using control measures, such as infiltration devices.

SLAMM was used to estimate runoff volume for the 25 storm events from all source areas in each basin. The sum of the volumes from all of these source areas was compared to the volume measured at the basin storm-sewer outfalls for these 25 events. Initially, the model overpredicted the water volumes measured at Monroe by a total of 55% (over the entire study period), whereas it underpredicted those measured at Harper by only 2%. To obtain a balance of overprediction and underprediction between the basins, the runoff coefficients were adjusted. Historically, more measurements have been made for runoff from impervious surfaces (Pitt, 1987) and more than 50% of the area within each basin is pervious, mostly because of residential lawns. Therefore, it was decided that the runoff coefficients for pervious areas were more uncertain and model calibration could benefit from minor adjustments.

Two sets of runoff coefficients are available for pervious areas; one is designed to represent clayey soils, and the other represents sandy soils. The predicted water volumes mentioned above were determined using the runoff coefficients for clayey soils (based on soil maps). Changing the pervious classification from clayey to sandy resulted in SLAMM underprediction of water volumes; approximately a 4% and a 42% underprediction at the Monroe and Harper Basin storm-sewer outfalls, respectively. A much better agreement was achieved at Monroe by assuming that the original soil classification was incorrect. Sandy and clayey runoff coefficients, available to the model, probably represented two extremes, and more realistic runoff coefficients fell somewhere between these two coefficients.

Lawn-runoff data collected from Monroe and Harper Basins were used to create runoff coefficients that more accurately represent the pervious conditions found in Madison. First, the rainfall depth sufficient to initiate runoff in SLAMM was changed using data on the amount of stormwater in the lawn-sample bottles after each event. For rainfall amounts less than approximately 0.3 in., the bottles were less than 10% filled. From this observation, 0.3 in. was established as the minimum precipitation required to initiate runoff. However, the runoff coefficient table for clayey soils used in SLAMM resulted in 10% runoff for a rainfall depth of 0.2 in. Hence, SLAMM was changed to initiate runoff at 0.3 in. rather than 0.2 in. of precipitation.

In addition to the change described above, a trial-and-error approach was used to change the coefficients until optimum agreement was reached between water volumes predicted in SLAMM and those measured at the Monroe and Harper storm-sewer outfalls. The resulting coefficients were between those for sandy and clayey soils and were approximately two-thirds the value for clayey soils. Figure 8 shows how the new "Madison" runoff coefficients compare to the sandy and clayey coefficients.

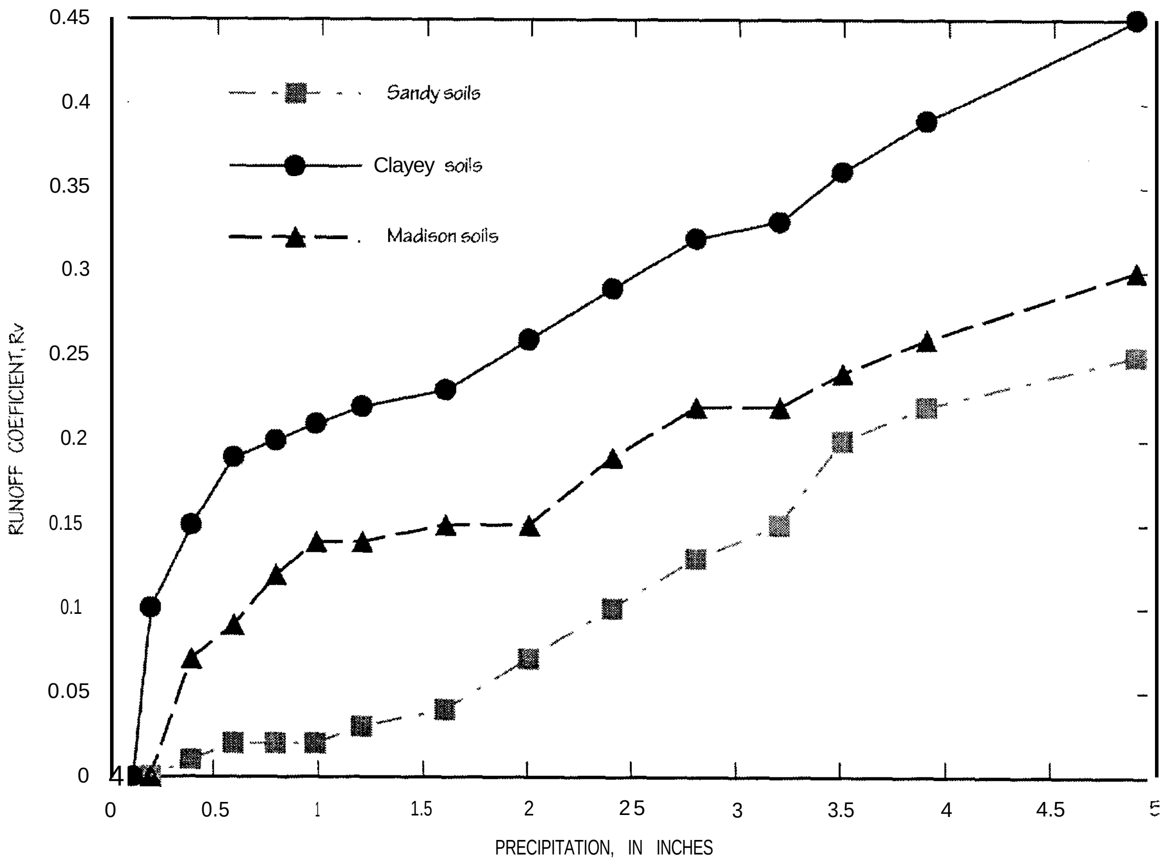

Figure 8. Madison runoff coefficients compared to sandy and clayey coefficients.

Based on the revised Madison runoff coefficients, SLAMM overpredicted storm-sewer outfall volumes at Monroe by 23% and underpredicted Harper storm-sewer outfall volumes by 24% (Table 4). The Madison coefficients also produced consistent lawn-runoff contributions in both basins, approximately 20% of the total volume. It is expected that the percentage of lawn contribution would be similar for both basins because they have nearly the same percentage of lawn area.

Table 4. Percentage Difference in Cumulative Modeled Water Volumes Compared with Measured Outfall Water Volumes Using Three Soil Types, Madison, Wi.

Basin	Sandy soils (%)	Clayey soils (%)	Madison soils (%)
Monroe	-4	55	23
Harper	-42	-2	-24

Sediment Calibration

Once the runoff volumes were calibrated, SLAMM was used to estimate sediment loads for the 25 events in each basin. With the exception of streets, a data base of sediment concentrations for each source area is used in SLAMM and these concentrations are applied to the water volumes to derive a load. Sediment concentrations from streets are computed by a wash-off function that is related to a street-dirt accumulation rate.

A mass-balance approach was used to test the source-area concentrations within each basin with those measured at the storm-sewer outfall. Source-area loads were computed by multiplying the water volumes produced from SLAMM by the concentrations measured at the source areas for each event and then summing these event loads. Sidewalks and woodlots were two of the larger unmonitored source areas in each basin, accounting for 12% and 1% of the water volume produced at Monroe and 7% and 2% at Harper, respectively. To add sidewalks to the load estimates, concentrations measured at driveways were applied to estimates at sidewalks to create a sidewalk load. Woodlot concentrations were estimated by use of data collected in an undeveloped urban site near Superior, WI (Steuer and others, 1997). The source-area loads were 39% lower and 60% lower than the measured load at the storm- sewer outfall in the Monroe and Harper Basins, respectively. This difference between source-area and storm-sewer outfall loads indicates that one or more source areas within each basin were not effectively monitored.

Streets were the most likely source area to be ineffectively monitored. Street samplers were placed approximately 5 ft away from the curb to prevent gutter flow into the sampler because gutter flow usually contains a mixture of water from several source areas. Other street studies (Pitt, 1979) have estimated that 90% of the dirt on residential streets in good condition with little to no parking accumulates within 3 ft of the curb. A larger amount of dirt can sometimes collect along the curb itself rather than in the driving lane. Some of this dirt could have been deposited on the driving lane, and turbulence from passing vehicles and wind may have moved it to the curb. Most street dir-t falls within 1 to 2 ft of the curb if the driving lane is next to the curb (Pitt, 1979). This information suggests that the street samplers in the Monroe and Harper Basins were too far from the curb (5 ft) to representatively collect the particulate dirt from the streets.

For the reasons previously described, a trial-and-error approach was used to select a street- sediment concentration that more accurately reflected the street sediment entering the storm sewer. The final suspended-solids concentrations for streets were increased by a factor of 5. Applying this factor to the simulated street suspended-solids concentration during each storm event allowed the sum of source-area loads to be within 7% and 9% of the storm- sewer outfall loads at Monroe and Harper, respectively (Table 5). The geometric means for the revised street suspended-solids concentrations were 340 and 325 mg/L for low- and high-traffic streets, respectively. These values were within 5% of those measured at both Marquette, MI (Steuer and others, 1997), and Madison, WI (Bannerman and others, 1993).

The geometric means of the observed suspended-solids concentrations, excluding streets, for the 25 storm events at Monroe and Harper Basins were placed into the SLAMM data base (Table 6). The suspended-solids concentrations for streets were not as easily altered because they are determined by dirt accumulation and wash-off functions in the model. Entering the geometric means enabled the model to more accurately predict the loads measured at the storm-sewer outfall. After summing the 25 events, sediment loads predicted by SLAMM were 17% lower at Monroe and 32% lower at Harper compared to the measured storm-sewer outfall loads.

To improve the match between measured and simulated storm-sewer outfall loads, the delivery coefficients were removed from SLAMM calculations, essentially assuming 100% delivery from source area to storm-sewer outfall. The delivery coefficients had been added in a previous calibration study to force a match to the storm-sewer outfall numbers. This adjustment resulted in a 4% and 17% undersimulation between storm-sewer outfall loads of suspended solids calculated by SLAMM and those measured at the storm-sewer outfall for Monroe and Harper, respectively (Table 5).

Phosphorus Calibration

One objective in calibrating phosphorus concentrations in SLAMM was to ensure that the Monroe and Harper Basins were accurately represented by the monitored source areas. The sum of source-area loads for total phosphorus for the
25

Table 5. Percentage Difference in Cumulative Source-area Sediment Loads, Before and After Sediment Adjustment, and Modeled and Measured Sediment Loads at the Basin Outfall, Madison, Wi. [Loads computed as suspended solids; %, percent]

Basin	Cumulative source area compared with storm-sewer outfall		
	Suspended solids before adjustment (%)	Suspended solids after adjustment (%)	Modeled compared with measured (%)
Monroe	-39	-7	-4
Harper	-60	-9	-17

Table 6. Suspended-solids Concentrations Used to Calibrate the Source Loading and Management Model for Basins in Madison, Wi. [mg/L, milligrams per liter: --, a series of algorithms and coefficients are used in the model to calculate a suspended-solids concentration for street runoff]

	Suspended solids (mg/L)	
Source area	**Residential**	**Commercial**
Driveways	34	34
Lawns	84	84
Parking lots	51	51
Streets	--	--
Woodlots	15	15
Roofs	16	18
Sidewalks	34	34

storm events was nearly identical to the storm-sewer outfall load (Table 7). The difference was larger for dissolved phosphorus, but no information was available to determine what adjustments should have been made to reduce the difference. For this reason, the unadjusted concentrations were entered into the SLAMM data base.

Table7. Percentage Difference Between Cumulative Source Area Versus Outfall Loads and Modeled Results Versus Outfall Loads, after Calibration of the Source Loading and Management Model for Basins in Madison, Wi. [%, percent]

Basin	Cumulative source area versus storm-sewer outfall		Model results after calibration versus storm-sewer outfall	
	Phosphorus load			
	Dissolved (%)	Total (%)	Dissolved (%)	Total (%)
Monroe	39	-1	-9	-24
Harper	**35**	**4**	-10	**-28**

The model simulates total phosphorus loads by adding the dissolved phosphorus and particulate phosphorus loads. For all source areas except streets, particulate-phosphorus concentrations were calculated using total- and dissolved-phosphorus and sediment concentrations measured at the Monroe and Harper Basins. To be consistent with calibration procedures, particulate-phosphorus concentration for street runoff was calculated using the adjusted value for sediment (an increase by a factor of 5). Changing the phosphorus concentrations resulted in SLAMM undersimulation of dissolved and total phosphorus by 9% and 24% at the Monroe storm-sewer outfall and 10% and 28% at the Harper storm-sewer outfall, respectively.

The dissolved- and particulate-phosphorus concentrations entered into the SLAMM data base are listed in Tables 8 and 9. Significant changes in dissolved-phos-phorus concentrations (Table 8) were observed for lawns (from 0.22 to 0.53 mg/L), streets (from 0.39 to 0.12 mg/L), woodlots (from 0.25 to 0.01 mg/L), and sidewalks (from 0.60 to 0.07 mg/L). With the exception of streets, where the particulate-phosphorus concentrations in runoff decreased, particulate-phosphorus concentrations increased significantly (Table 9).

Table 8. Dissolved-phosphorus Concentrations Used to Calibrate the Source Loading and Management Model for Basins in Madison, Wi.
[mg/L, milligrams per liter]

	Dissolved phosphorus (mg/L)	
Source-area	**Residential**	**Commercial**
Driveways	0.07	0.07
Lawns	.53	.53
Parking lots	.02	.02
Streets	.12	.03
Woodlots	.01	.01
Roofs	.04	.02
Sidewalks	.07	.07

Table 9. Particulate-phosphorus Concentrations Used to Calibrate the Source Loading and Management Model for Basins in Madison, Wi.
[mg/kg, milligrams per kilogram]

	Particulate phosphorus (mg/kg)	
Source area	**Residential**	**Commercial**
Driveways	2,649	2,649
Lawns	4,943	4,943
Parking lots	1,467	1,467
Streets	569	409
Woodlots	5,000	5,000
Roofs	3,777	7,946
Sidewalks	2,649	2,649

Distribution of Source-Area Loads

The distribution of suspended-solids and total- and dissolved-phosphorus loads for source areas in the Monroe and Harper Basins using measured source-area concentrations multiplied by SLAMM-generated water volumes is shown in Table 10. The distribution of water volumes is nearly identical at Monroe and Harper Basins. The percentage of the total basin represented by each source area is similar for both basins (Table 1); thus, one should expect to see similar relative volumes of water calculated from both basins. Streets contributed most of the suspended-solids loads at both Monroe and Harper Basins, generating 81% and 73%, respectively. Lawns contributed more than 10% of the solids loads at both basins. The phosphorus loading, however, was quite different. Lawns in the Harper Basin generate more than two-thirds of the phosphorus loads, whereas phosphorus in the Monroe Basin is more evenly distributed between lawns and streets. These differences in load distribution are the result of the measured phosphorus concentrations, especially for lawns, which are much higher for the Harper Basin (Table 2).

Table 10. Distribution of Loads Based on Measured Values at Monroe and Harper Basins, Madison, Wi, and Incorporating the Suspended-solids Adjustment [N/A, source area not present; %, percent abundance; --, value less than 0.5 percent]

Source area	HARPER Water volume[1] (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)	MONROE Water volume (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)
Lawns	21	15	67	71	20	10	44	45
Streets	37	73[2]	14	11	38	[2]81	37	39
Driveways	18	7	9	9	12	2	5	4
Sidewalks	7	3	4	3	14	3	5	4
Parking lots	3		1	--	6	2	1	
Roofs	11		3	4	7	--	1	--
Parks		--	2	2	3	2	7	7
Woodlots	3	--	--	--	N/A	N/A	N/A	N/A
Other	N/A	N/A	N/A	N/A	1	--	--	--
Total	311,122	3,598	9	5	2,417,341	26,045	70	33

[1] Water volume totals expressed in cubic feet; all other totals expressed in pounds.
[2] Street-runoff concentrations multiplied by 5.

The suspended-solids load distribution at the Monroe Basin in 1994 is similar to the distribution observed in a 1991 study (Bannerman and others, 1993). Streets contributed 80% of the total basin suspended-solids load in 1991 and 81% in 1994. Lawns also were comparable, contributing 7% and 10% of the total basin suspended-solids load in 1991 and 1994, respectively. Total and dissolved phosphorus, however, were very different. During the 1991 study, the proportion of the total-phosphorus load from streets (58%) outweighed that for lawns (14%). The same was true in 1991 for dissolved phosphorus, where streets produced 46% and lawns 22% of the basin load. However, most total- and dissolved-phosphorus loading in 1994 was attributed to lawns rather than streets. Streets and lawns, in 1994, generated 37% and 44% of the total-phosphorus load and 39% and 45% of the dissolved- phosphorus load in the Monroe Basin. The difference in distributions between the two studies is possibly due to differences in sampling methodology. The street-sampler design was modified for the 1994 study to eliminate a first-flush effect, where the sample bottle would quickly fill with stormwater and act as a sediment trap for the remaining duration of the storm event. Also, during the 1994 study, 25 events were monitored, whereas only 10 events were monitored in 1991. This larger sample size in 1994 improves confidence in the loading-distribution estimates.

Distribution of suspended-solids, total-phosphorus, and dissolved-phosphorus loads estimated by SLAMM are given in Table 11. The distribution of loads is consistent with the distribution of measured loads shown in Table 10. For each constituent, slightly less total load was simulated with SLAMM than calculated using the measured concentrations (other than suspended solids from streets), yet the distributions of each constituent were similar. Streets and lawns contribute nearly all of the suspended-solids load for the entire basin. Streets alone contribute more than 75% of the suspended solids at both Monroe and Harper Basins. Additionally, the significance of lawns as generators of phosphorus is again noted in SLAMM simulations. Lawns in the Harper Basin contribute 52% and 61% of total and dissolved phosphorus loads, and lawns in the Monroe Basin contribute 49% and 57%. Streets contribute the second largest phosphorus loads (about 25%), whereas driveways and sidewalks combined contribute approximately 10%.

The distribution of suspended solids and total and dissolved phosphorus for source areas in the Monroe and Harper Basins using measured source-area concentrations multiplied by SLAMM-generated water volumes is shown in Table 12. Only loads for the source areas measured are shown in Table 12; concentrations of suspended solids in street runoff have not been adjusted. These source areas accounted for 82% and 90% of the total water volume from the Monroe and Harper Basins, respectively.

Table 11. Distribution of Loads from Model Simulation Results at Monroe and Harper Basins, Madison, Wi. [N/A, source area not present; %, percent abundance; --, value less than 0.5 percent]

	HARPER				MONROE			
Source area	Water volume (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)	Water volume (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)
Lawns	21	11	52	61	20	12	49	57
Streets	37	81	32	24	38	77	26	22
Driveways	18	4	8	7	12	3	5	4
Sidewalks	7	1	3	3	14	3	6	5
Parking lots	3	1	1		6	2	1	
Roofs	11	1	3	2	7	1	2	--
Parks		--	2	2	3	2	8	9
Woodlots	3	--	1	--	N/A	N/A	N/A	N/A
Other	N/A	N/A	N/A	N/A	1	1	2	2
Total	311,122	3,170	7	4	2,417,341	20,814	60	29

[1] Water volume totals expressed in cubic feet; all other totals expressed in pounds.

Table 12. Distribution of Loads from Monitored Source Areas Only, Based on Unadjusted Concentrations at the Monroe And Harper Basins, Madison, Wi. [%, percent abundance; percentage columns may not add up to 100% because of independent rounding]

	HARPER				MONROE			
Source area	Water volume (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)	Water volume (%)	Suspended solids (%)	Total phosphorus (%)	Dissolved phosphorus (%)
Lawns	23	41	70	75	24	28	56	69
Streets	41	43	20	15	46	53	33	21
Driveways	20	10	7	6	14	9	7	8
Parking lots	4	3	1	0	7	7	2	1
Roofs	12	3	3	4	9	3	2	1

The suspended-solids distributions shown in Table 12 differ from Tables 10 and 11, in that the significance of lawns as a source increases and the significance of streets as a source decreases. Streets are still the largest source of suspended solids in both basins. The phosphorus distributions also change, but not as much as the suspended solids because the measured phosphorus concentrations were used in all three tables (Tables 1 0, 1 1, and 12). The significance of lawns as a source increases slightly, and streets are a slightly larger source in some cases, and in others, are slightly smaller sources. Results shown in Table 12 indicate that the adjustments made to suspended-solids concentrations in street runoff do not greatly affect the phosphorus distributions in the basins.

Sediment and Phosphorus Mass in Street-Dirt Samples

Approximately 75% of the total sediment mass in the street-dirt samples originated in the >250 μm size fraction, whereas the smaller fractions (<63 μm) made up less than 5%. Material composed of leaves, twigs, and other organic debris also were measured, contributing, on average, less than 10% of the total sediment mass of the sample (Figure 9).

Like sediment mass, the largest amount of total phosphorus was found in the >250 μm size fraction (nearly 50%) (Figure 9). Combining this size fraction with the leaf fraction, about 80% of the total phosphorus is accounted for. The contribution of total phosphorus mass decreased as the size fraction decreased. Other studies have shown that large phosphorus concentrations correspond with small particle sizes because of the high surface area to mass ratio for small particles (Sartor and Boyd, 1972).

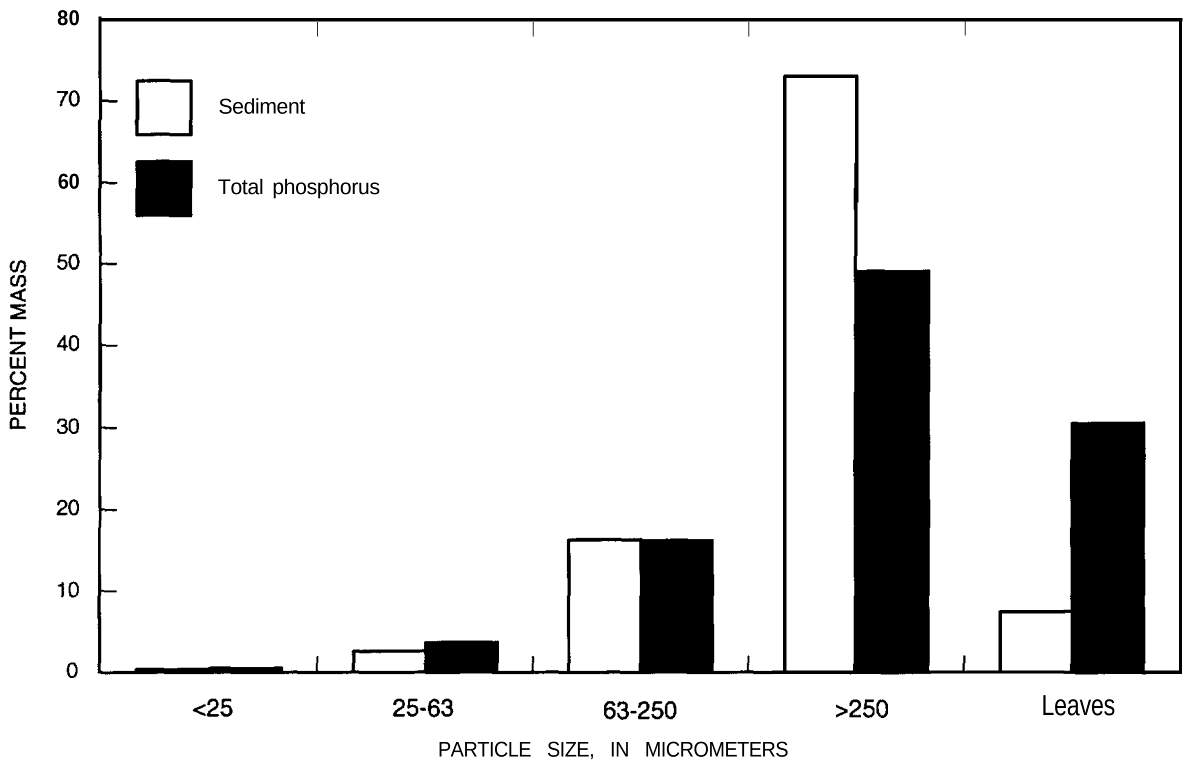

Figure 9. Relations between sediment and total-phosphorus mass from street-dirt samples for five particle-size fractions for basins in Madison, WI

However, the bulk of the phosphorus phosphorus load results from the greater particle-size fractions (Ray, 1997). Approximately 25% of the total phosphorus mass in each size fraction can be attributed to leaves (Ray, 1997).

A recent study of particle-size distribution in stormwater at the Monroe storm-sewer outfall demonstrated that most of the solids are in the particle sizes <63 ?m (Greb and Bannerman, 1997). This distribution is the opposite of the particle-size distribution observed for the street dirt collected in this study. These results indicate either a loss of the larger particles somewhere between the street and the outfall or a problem in collecting larger particles in the runoff samples. Most of the larger particles (>63 ?m) might settle out before reaching the storm-sewer outfall. Street sweeping, resuspension onto street terraces, and catch basins can remove these particles from the streets before they reach the storm sewer. Also, the transport of large particles in a storm sewer is not as efficient as the transport of smaller, more mobile particles. Large sediment particles may become trapped or part of the bedload before reaching the sampler. Bedload is not sampled efficiently by the automatic samplers described earlier in this report.

Summary and Conclusions

Concentrations of suspended solids, total phosphorus, and dissolved phosphorus were collected from various source areas at two urban residential basins in Madison, WI. To represent a range of source-area concentrations for urban residential basins in Madison, the geometric means of the combined concentration data from the Monroe and Harper Basins were incorporated into the urban-runoff model, SLAMM.

Source-area suspended solids and phosphorus loads from the Monroe and Harper Basins were determined based on measured concentrations that were multiplied by water volume estimated by use of SLAMM. Collected data were used to calibrate and increase confidence in water volumes, suspended solids, and phosphorus source-area loads estimated by SLAMM. The calibrated model calculated water volumes to within 23% and 24% of those measured at the outfalls of the Monroe and Harper Basins. These calibrated water volumes were then applied to the calibrated suspended-solids and phosphorus concentrations entered into the SLAMM data bases. Suspended-solids loads were estimated by the calibrated SLAMM to be within 4% and 17%, total-phosphorus loads within 24% and 28%, and dissolved-phosphorus loads within 9% and 10% of those measured at the storm-sewer outfall to the Monroe and Harper Basins, respectively.

Streets and lawns are the largest contributors of suspended-solids, total-phosphorus, and dissolved-phosphorus loads in a residential urban basin. Lawns are the largest contributors of total and dissolved phosphorus; however, streets contributed nearly 40% of the basin load, as seen in the Monroe Basin. Streets were found to be the largest source of suspended solids.

There was a large difference between geometric mean concentrations of phosphorus in lawn runoff from 1994 to 1995. Phosphorus data collected from lawns in the Harper and Lakeland Basins during 1995 are remarkably similar, which suggests that the phosphorus concentration in lawn runoff is affected by some variable or variables that are not yet understood.

Street-dirt samples indicate that approximately 75% of the sediment mass resides in the >250 pm particle-size fraction. Less than 5% of the mass can be found in the particle sizes less than 63 μm. The >250 μm particle-size fraction also contributed nearly 50% of the total- phosphorus mass, and the leaf fraction contributed an additional 30%. In each particle-size fraction, approximately 25% of the total-phosphorus mass is derived from leaves or other vegetation.

A possible limitation of this study may be that in order for the sum of the source-area loads to match the basin-outfall loads, it was assumed that the concentrations of suspended solids in street runoff were about 5-times higher than the concentrations measured. However, the analysis of load distributions based only on unadjusted monitoredconcentration data shows little change in the distributions. In addition, samples from more rain events were collected in this study than previous source-area studies. Also, improved data-collection equipment were used during this study. Both of these factors lead to greater confidence in the study results.

Most of the measured suspended-solids concentrations were lower than those measured from previous studies. However, when comparing concentration results in this study to results from earlier studies, it is important to note that with the exception of the Marquette study, previous studies used earlier generation source-area sampling equipment. In Marquette, Ml, the soils are considerably more sandythan those in Madison, which may explain why the suspended-solids concentrations determined for the Marquette study are higher than those from Madison even though both studies used the same sample-collection equipment.

The recalibration of the SLAMM model results in an improved model that should more accurately simulate phosphorus and sediment runoff loads in Wisconsin than the earlier version of the model. The newly created lawn-runoff coefficients for Madison represent a compromise between the two previous soil-type options available for model input, which probably represented runoff extremes. The runoff coefficients calculated for Madison should probably be applied to most urban lawns in Wisconsin unless soils are known to be either sandy or clayey. The phosphorus- and sediment-concentration data bases created for this study are the largest to date using the most advanced source-area sample collection technology available.

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Using Biological Criteria to Assess and Classify Urban Streams and Develop Improved Landscape Indicators

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Abstract

This study consisted of a quantitative analysis of the relationship between the Index of Biotic Integrity (IBI), an indicator of urban land use, and a qualitative analysis of overlying stressors in six of the major metropolitan areas of Ohio. A database consisting of 267 sampling locations was extracted from the Ohio EPA statewide biological and habitat database. Most of these sites were sampled between 1990 and 1998 and contained watershed areas less than 50 $mi.^2$, with most draining less than 20 $mi.^2$. A negative relationship between IBI and urban land use was observed in four of the six areas, whereas little or no relationship was seen in two areas. For each area, the highest percentage of urban land use that corresponded to minimum attainment of the applicable warmwater habitat IBI biocriterion ranged from 1% (Cleveland/Akron) to 12% (Dayton) for the regression line, and 15% (Cleveland/Akron) to 58% (Columbus) as the highest %urban land use where the IBI biocriterion was attained at any given site. No significant linear relationship was found in either the Toledo or Youngstown areas, and only a weak relationship was visually apparent for the Toledo streams. The lack of association was due to the strong presence of overlying stressors (e.g., legacy pollutants, sewage discharges, combined sewer overflows) that resulted in very low IBI values at sites with lower levels of urbanization. The percentage of urban land use explained approximately 35% of the variation in IBI scores in the regression model when these impact types were excluded (compared to 11% when included). The maximum %urban land use that commonly corresponded to attainment of the warmwater habitat IBI biocriterion based on inspection of the scatter plot was approximately 26%. Only a very few sites exhibited attainment at urban land uses between 40-60% and none occurred above 60%. These former sites had either an intact, wooded riparian zone, a continuous influx of groundwater, and/or the relatively recent onset of urbanization. These results indicate that it might be possible to mitigate the negative effects of urbanization by preserving or enhancing near and instream habitats, particularly the quality of the riparian buffer zone. The results also suggest that there is a threshold of watershed urbanization (e.g., >60%) beyond which attainment of warmwater habitat is unlikely. This threshold is not the same in all watersheds and it can occupy a rather wide range. It is affected by co-factors such as pollutant loadings, watershed development history, chemical stressors, and watershed scale influences such as the quality of the riparian buffer and the mosaic of different types of land use. Thus, single-dimension urban land use indicators, such as watershed imperviousness, are not sufficiently precise or robust as a single indicator of use attainability. The further development and refinement of multiple indicators of watershed urbanization has merit from a management and decision-making standpoint. We suggest that co-factors, in addition to more refined urban land use indicators, be better developed. More precise definitions of different urban land uses are also needed to better understand and respond to the water quality management challenges posed in existing and developing urban areas.

Introduction

The health and well-being of the aquatic biota in surface waters is an important barometer of how effectively we are achieving the goals of the Clean Water Act (CWA); namely the maintenance and restoration of biological integrity, and the basic intent of water quality standards. States designate water bodies for beneficial uses (termed designated uses) that, along with chemical, physical, and biological criteria, assure the protection and restoration of aquatic life, recreational, and water supply functions and attributes. Biological criteria are the principal tool for determining impairment of designated aquatic life uses as defined by the Ohio WQS (Ohio Administrative Code 3745-l). As such, bioassessments play a central role in the Ohio Nonpoint Source Assessment (Ohio EPA 1990; 1991), the biennial Ohio Water Resource Inventory (305b Report; Ohio EPA 1998), and watershed-specific assessments, of which Ohio EPA completes between 6 and 12 each year. Biological criteria represent a measurable and tangible goal, against which the effectiveness of pollution control and other water quality management efforts can be judged. However, biological assessments must be accompanied by appropriate chemical/physical measures, land use characterization, and pollution source information necessary to establish linkages between stressors and the biological responses (Yoder and Rankin 1998). Biological criteria in the Ohio WQS also supports the determination of appropriate aquatic life use designations for individual water bodies, provides for a "reality check" on the application of surrogate indicators, assesses cumulative impacts, extends anti-degradation concerns to nonpoint sources and habitat influences, defines high quality waters, and serves as a meaningful indicator in the management of regulatory programs for environmental results. This provides a means to incorporate the broader concept of water resource integrity (Karr et al. 1986) in policy and planning while preserving the appropriate roles of the traditional chemical/physical and toxicological approaches developed over the past three decades.

We, and others at Ohio EPA, have previously described the status of Ohio's streams and rivers as affected by watershed urbanization (Yoder et al. 1999; Yoder and Rankin 1997; Yoder 1995). Small watersheds are especially impacted, as illustrated by Yoder and Rankin (1997), where no headwater streams in established urban settings throughout Ohio attained the minimum CWA benchmark use designation of warmwater habitat. This finding has led to the perception that the impairment of beneficial aquatic life uses in these small watersheds is intractable, at least within the constraints of current land use policies, restoration technologies, and funding levels. Together, these factors present potentially significant barriers to the objective of fully restoring degraded watersheds or upgrading urban streams that are presently designated for less than fishable and swimmable uses.

Headwater streams are critical to watershed functioning in that they serve as the principal interface between runoff from land use and receiving streams. The ability of a headwater stream to physically filter and biologically assimilate the primary and secondary effects of pollutants is a function of habitat quality and the structure of the biological system. A healthy headwater stream ecosystem is characterized by good habitat and a well balanced assemblage of aquatic organismsand plants, one which processes external inputs in a manner which promotes high quality downstream exports. These exports include good quality water and high value biomass, both of which positively impact the ability of downstream waters to deliver quality goods and services (e.g., water supply, recreation, waste assimilation, water retention, ecological values). A degraded headwater stream ecosystem is characterized by poor habitat and an assemblage of aquatic organisms and plants that processes external inputs in a manner which promotes low quality downstream exports. Thus in this latter scenario, the effects from urban runoff can accumulate in a downstream direction and adversely affect water quality and ecosystem goods and services in larger water bodies. In Ohio, more than 78% of stream miles drain less than 20 mi.^{2} and are classified as headwater streams. While these may individually seem less significant than larger water bodies, they are collectively the most numerous and perhaps important stream type. In many ways, and in a collective sense, headwater streams are analogous to the capillaries of the human circulatory system where essential product transport and waste assimilation functions are accomplished. Certainly the finding that a high proportion of headwater streams fail to meet CWA goals in Ohio urban areas translates to the potential for undesirable impacts in downstream waters and obvious consequences for the overall health of the "patient".

There is concern that the attainment of CWA goal uses (e.g., warmwater habitat in Ohio) within small urban watersheds may be precluded by the legacy of urbanization. If this is true, how is this determined and what are the protection endpoints to guide water quality management? Federal water quality standards regulations (40CFR, Part 131) allow for the establishment of a use that is less than the CWA fishable and swimmable goals when it is precluded by the following:

1) the degraded conditions are naturally occurring;

2) restoring the degraded conditions would result in widespread adverse socioeconomic impacts;

3) the degraded conditions are irretrievable and human induced.

Such uses are established on a waterbody-specific basis and are supported by a use attainability analysis. In Ohio, such analyses are routinely conducted as a result of the five-year basin approach to monitoring, assessment, and water quality management. One purpose of this paper is to advance the development of the tools and indicators needed to make use attainability decisions in urban watersheds.

Ohio EPA routinely conducts biological and water quality surveys, or "biosurveys", on a systematic basis statewide. A biosurvey is an interdisciplinary monitoring effort coordinated on a waterbody-specific or watershed scale. Such efforts may be relatively simple, focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites; or much more complex, including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year, Ohio EPA conducts biosurveys in 1 O-l 5 different study areas with an aggregate total of 350-450 sampling sites. Biological, chemical, and physical monitoring and assessment techniques are employed in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. The findings and conclusions of each biological and water quality study may factor into regulatory actions taken by Ohio EPA and are incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] Report).

In 1990, the Ohio EPA initiated an organized, sequential approach to monitoring and assessment, termed the Five-Year Basin Approach. One of the principal objectives of this new approach was to better coordinate the collection of ambient monitoring data so that information and reports would be available in time to support water quality management activities such as the reissuance of NPDES permits and periodic revision of the Ohio Water Quality Standards (WQS). Ohio EPA's approach to surface water monitoring and water quality management via the Five-Year Basin Approach essentially serves as an environmental feedback process taking "cues" from environmental indicators to effect needed changes or adjustments within water quality management. The environmental indicators used in this process are categorized as stressor, exposure, and response indicators (Yoder and Rankin 1998). *Stressor* indicators generally include activities that impact, but which may or may not degrade the environment. This includes point and nonpoint source loadings, land use changes, and other broad-scale influences that generally result from anthropogenicactivities. *Exposure* indicators include chemical-specific, whole effluent toxicity, tissue residues, and biomarkers, each of which suggests or provides evidence of biological exposure to stressor agents. Responseindicators include the direct measures of the status of use designations. For aquatic life uses, the community and population response parameters that are represented by the biological indices that comprise Ohio EPA's biological criteria are the principal response indicators.

Previously, our analyses examined the water quality and biological assessment database from watersheds in and near existing and developing urban and suburban areas of Ohio. Yoder and Rankin (1997) compiled their analyses based on sampling conducted at more than 100 stream sampling locations. Yoder et al. (1999) examined more detailed land use and stressor relationships with the Index of Biotic Integrity (IBI), based on fish assemblage data, and the Invertebrate Community Index (ICI), based on macroinvertebrate assemblage data, within two major Ohio urban areas (Akron/Cleveland and Columbus). This study consisted of a quantitative analysis of the relationship between the IBI, an indicator of urban land use, and a qualitative analysis of other stressors influencing this relationship using available data from all six of the major metropolitan areas within Ohio. The importance of understanding these relationships is heightened by contemporary water quality management issues such as combined sewers and stormwater permitting. One challenge we faced was in attempting to separate the influences of these multiple stressors on aquatic life attainment status. Could we sufficiently understand the baseline influence of urbanization apart from these other and better understood stressors?

The principal analysis conducted in this study examined the relationship between urban land cover and the IBI, both visually and by statistical analysis. Some goals were to determine the extent to which biological performance (as expressed by the IBI) was correlated with urban land use, thresholds at which this occurred, and the overlying effects of other stressors.

Met hods

A database consisting of 267 sampling locations from the six major metropolitan areas of Ohio was extracted from the Ohio EPA statewide biological and habitat database. Most of these sites were sampled between 1990 and 1998 and contained watershed areas less than 50 $mi.^2$, with most draining less than 20 $mi.^2$. As such, the database represents a collection of discrete watershed units where land uses may have a significant effect on the composition and quality of the instream habitat and biological communities. Urban land use effects have been much more apparent in these smaller watersheds as evidenced by the higher proportion of impaired stream miles compared to larger streams and rivers in Ohio (Yoder 1995; Yoder and Rankin 1997).

Fish communities were sampled using generator-powered, pulsed D.C. electrofishing units and a standardized methodology (Ohio EPA 1987a,b, 1989a,b; Yoder and Smith 1999). Fish community attributes were collectively expressed by the Index of Biotic Integrity (IBI; Karr 1981; Karr et al. 1986), as modified for Ohio streams and rivers (Yoder and Rankin 1995; Ohio EPA 1987b, 1989b). Habitat was assessed at all fish sampling locations using the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989, 1995). The QHEI is a qualitative, visual assessment of the functional aspects of stream macrohabitats (e.g., amount and type of cover, substrate quality and condition, riparian quality and width, siltation, channel morphology, etc.). Ohio EPA also collected macroinvertebrate assemblage data at some of these sites, but it was not included in this study because of the partial coverage and the extensive use of the qualitative method was not always compatible with regression analysis. Some of the analyses in our earlier studies (Yoder et al. 1999) included macroinvertebrate data.

The urban land use indicator was derived from Landsat Thematic Mapper satellite imagery of land cover classification (September 1994) provided by the Ohio Department of Natural Resources. The percentage of land use in the urban classification was calculated for the subwatershed upstream from each fish sampling location to the boundary of the watershed. Because many of the sites included in the statewide data set are subjected to a variety of stressors, each site was qualitatively classified by predominant impact type. Impact types included least impacted sites, estate sites (i.e., subwatersheds with large lot sizes or green space provided by parks), sites reflecting gross instream habitat alterations (i.e., channel modifications or impoundment), sites impacted directly by discharges from combined sewer overflows (CSOs), sites impacted by wastewater treatment plant discharges, sites impacted by instream sewer line placement and construction (Cincinnati area only), sites with evidence of impacts by legacy pollutants, or sites affected by general urbanization only. This latter category included urban land uses not containing any of the other impact types and usually consisted of residential development.

Results

The relationship between the IBI and urban land use was initially characterized by regressing IBI scores against percent urban land use (log,, transformed) and QHEI scores using a database of 267 sites for all of the six major metropolitan areas of Ohio (Figure 1). Diagnostic plots (e.g., residuals, normal probability) indicated nonconstancyof error variance. To provide insights into whether the results varied substantially between each metropolitan area, scatter plots of the relationship between urban land use and IBI in each of the six metro areas were also made (Figure 2). A negative relationship between IBI and urban land use was observed in four of the six areas, whereas little or no relationship was seen in two areas. For each area, the highest percentage of urban land use that corresponded to minimum attainment of the WWH IBI biocriterion was determined by inspection of the scatter plot and the intersection of the regression line and the WWH IBI biocriterion were determined (Figure 2). This ranged from 1% (Cleveland/Akron) to 12% (Dayton) for the regression line, and 15% (Cleveland/Akron) to 58% (Columbus) as the highest %urban land use where WWH was attained in each area at a given sampling location. No significant linear relationship was found in either the Toledo or

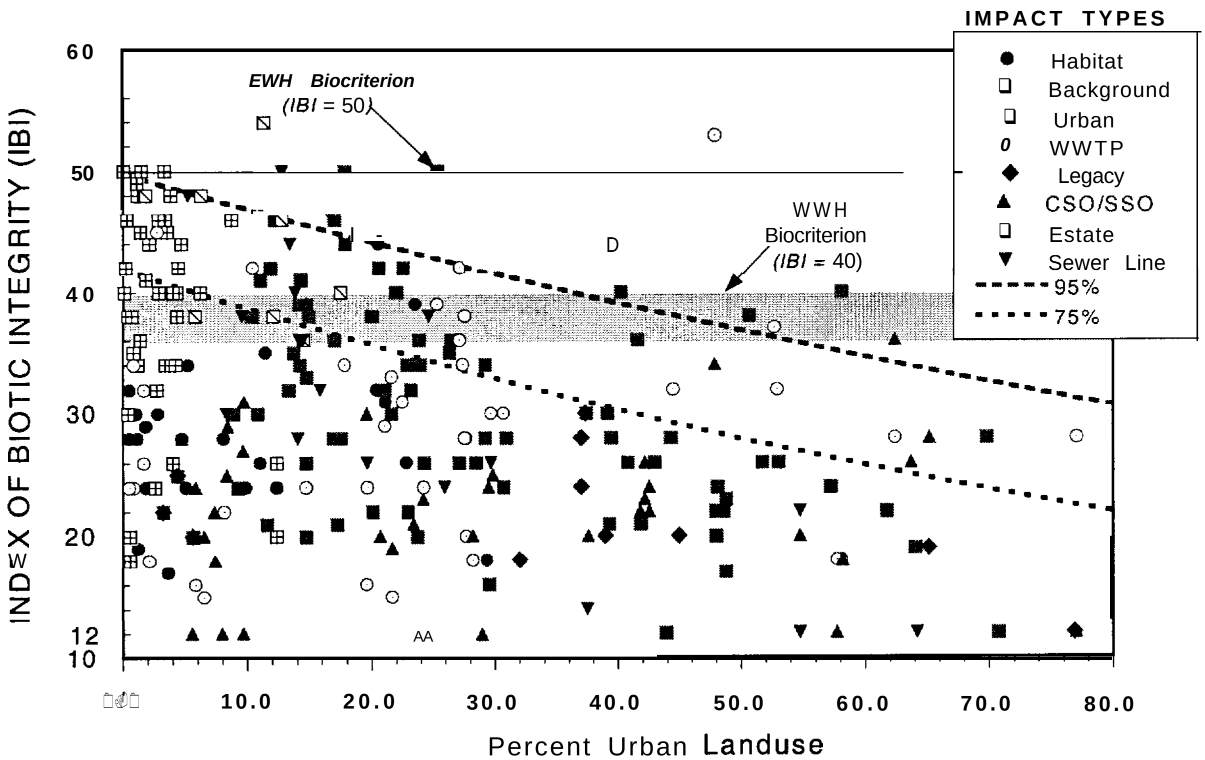


Figure 1. Scatter plot of Index of Biotic Integrity (IBI) scores against percentage of watershed upstream from the site in urban land use at 267 small (<50 mi.^{2}) sampling sites.

Youngstown areas, and only a weak relationship was visually apparent for the Toledo streams. All of the sites in the Youngstown area were impaired, and so severely that no land use relationship was evident (Figure 2). In the Toledo area, the highest urban land use corresponding to WWH attainment was 28%. However, the WWH IBI biocriterion in the Huron/Erie Lake Plain ecoregion is the lowest in the state and almost all of the small streams in the Toledo area have been channel modified to some degree. It was apparent that the lack of a stronger association between IBI and urban land use was due to overlying stressors (e.g., legacy pollutants, WWTPs, CSOs/SSOs), particularly those that resulted in very low IBI values at sites with low levels of urbanization. While some threshold relationships were evident in these results, the resulting variability in IBI scores led to only weak or non-existent linear relationships.

Some of the impact types had a strong effect on the IBI regardless of the effect of urban land use. The IBI results were examined by impact type across all six metro areas (Figure 3). The legacy, CSO/SSO, habitat, and WWTP impact types had the strongest negative effects on the IBI, respectively, and this was independent of the urban land use indicator. While these impact types are common to urban areas, they were removed from the remaining statistical analyses (elimination of these impact types reduced the sample size to 123 sites) to better develop the IBI/urban land use relationship. The entire Toledo and Youngstown datasets were also removed since they are comprised entirely of these impact types. This resulted in a better regression model fit, and diagnostics consistent with regression model assumptions (Neter et al. 1990). This also allowed us to discern the threshold of urbanization at which WWH attainment is lost with greater precision and in the absence of potentially confounding impacts, which was a major objective of our study. The relationship between different levels of urbanization and biotic integrity was further quantified with an analysis of variance model where quartiles of percent urban land use determined factor level (e.g., all sites within the 1 st quartile of percent urban land use were coded as factor level 1). Similarly, an analysis of covariance model using QHEI as the covariate was employed to test for further refinements. Multiple comparisons of factor level mean differences were made using Tukey's method (Neter et al., 1990).

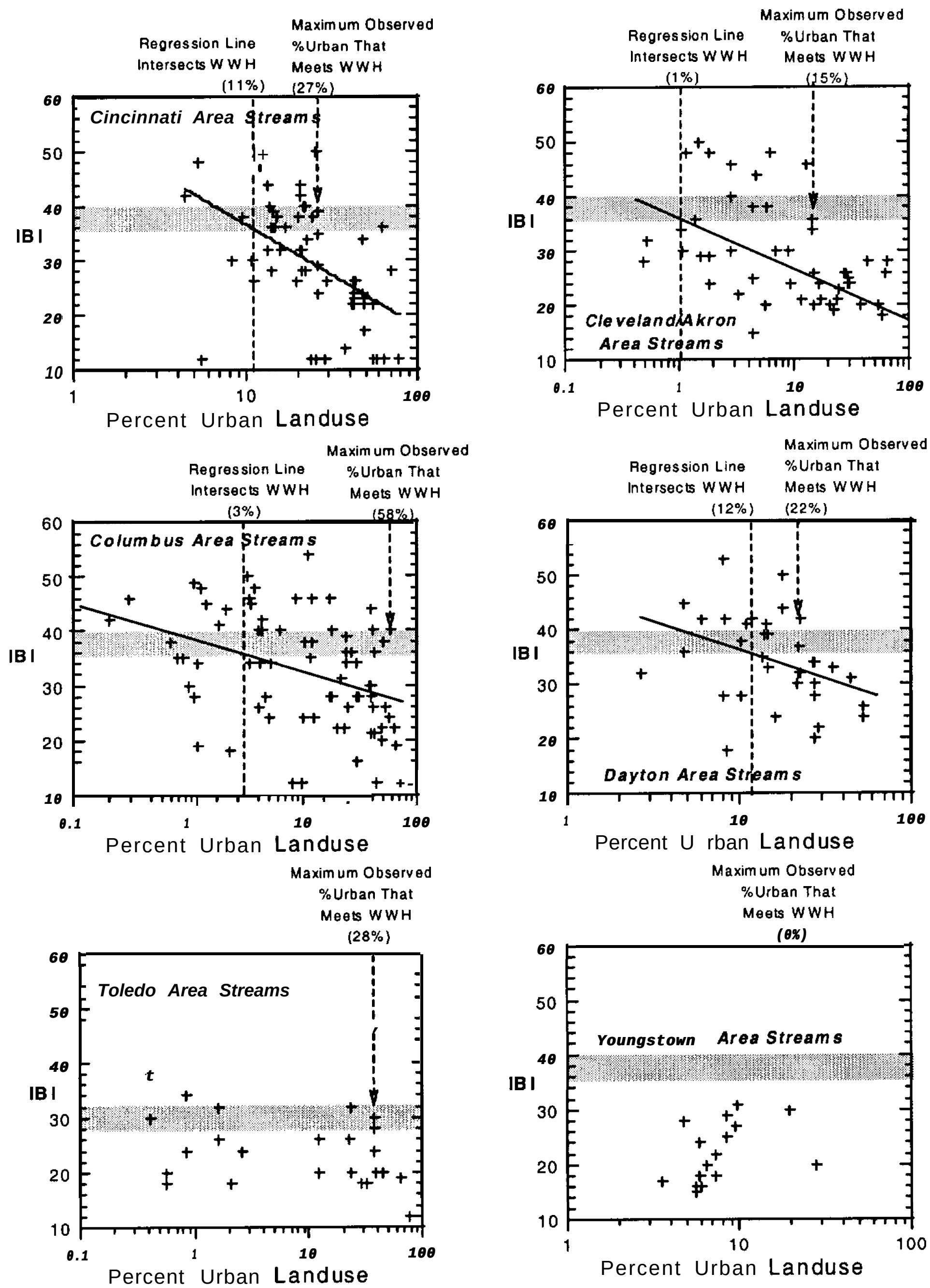
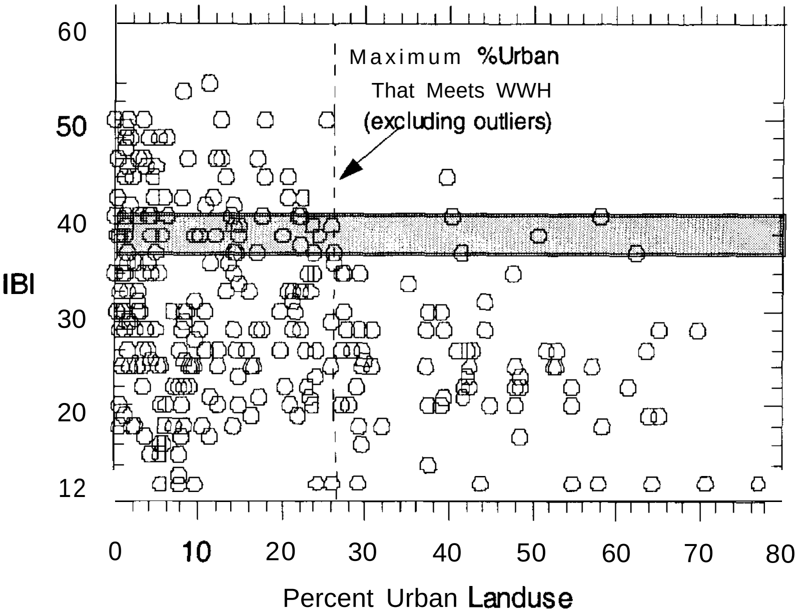


Figure 2. Scatter plots of Index of Biotic Integrity (IBI) scores against percentage of watershed upstream from the site in urban land use at small stream (<50 mi.^{2}) sampling sites in six of the major metropolitan areas of Ohio. Predominant impact types are indicated for each site (see Figure 1) along with the regression line. The warmwater habitat and exceptional warmwater habitat biological criteria for the IBI are also indicated.



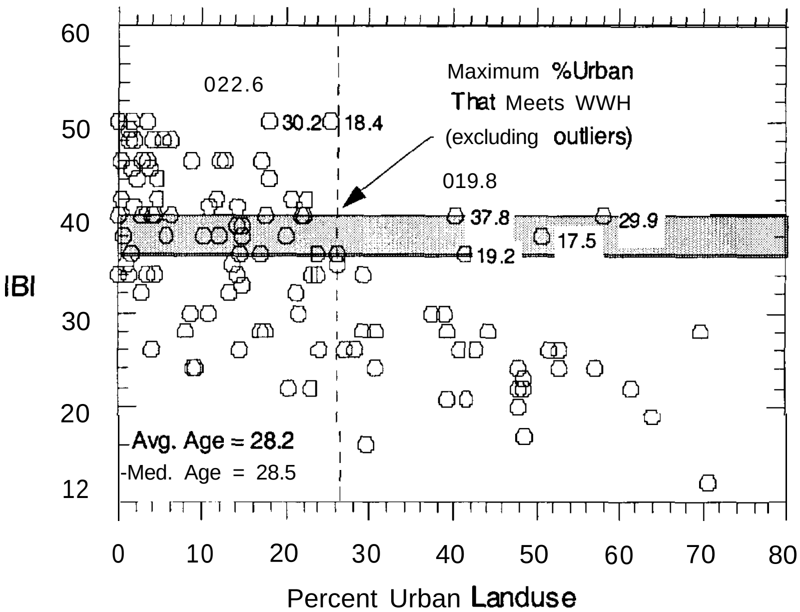


Figure 3. Box-and-whisker plots of Index of Biotic Integrity (IBI) scores by each of the major impact types used in Figures 1 and 2. The warmwater habitat and exceptional warmwater habitat biological criteria for the IBI are indicated.

The percentage of urban land use explained approximately 35% of the variation in IBI scores in the regression model when the other impact types were excluded. Local habitat quality (as measured by the QHEI) explained an additional 7% of the variation (Table 1). The ANOVA model showed that there were significant differences in mean IBI scores between quartile level of percent urbanization, with sites exceeding 29 % urban land cover having lower IBI scores on average than sites with less urban land cover (Figure 4). Sites characterized by less than 4% urban land cover had higher IBI scores than sites with urban land use exceeding 15% The ANCOVA model provided a slightly better fit, but the additional variation explained was marginal (Table 2), and the results of pairwise comparisons were similar between models (Figure 4).

Table **1.** Regression Results for the Model Ibl = Log_{10}(Percent Urban Land Use+l)+qhei for All Sites and the Removal of Selected Impact Types.

Effect	**Coefficient**	**SE**	**t**	**P(2 Tail)**	**Adj. R-Squared**
All Sites					
CONSTANT	21.9333	2.9450	7.4477	0.0000	
Urban	-6.8323	1.1370	-6.0092	0.0000	0.1179
QHEI	0.2676	0.0418	6.4102	0.0001	0.2388
Impact Types Removed					
CONSTANT	32.4069	4.2184	7.6822	0.0000	
Urban	-11.1496	1.3102	-8.5096	0.0000	0.3500
QHEI	0.2390	0.0605	3.9493	0.0001	0.4199

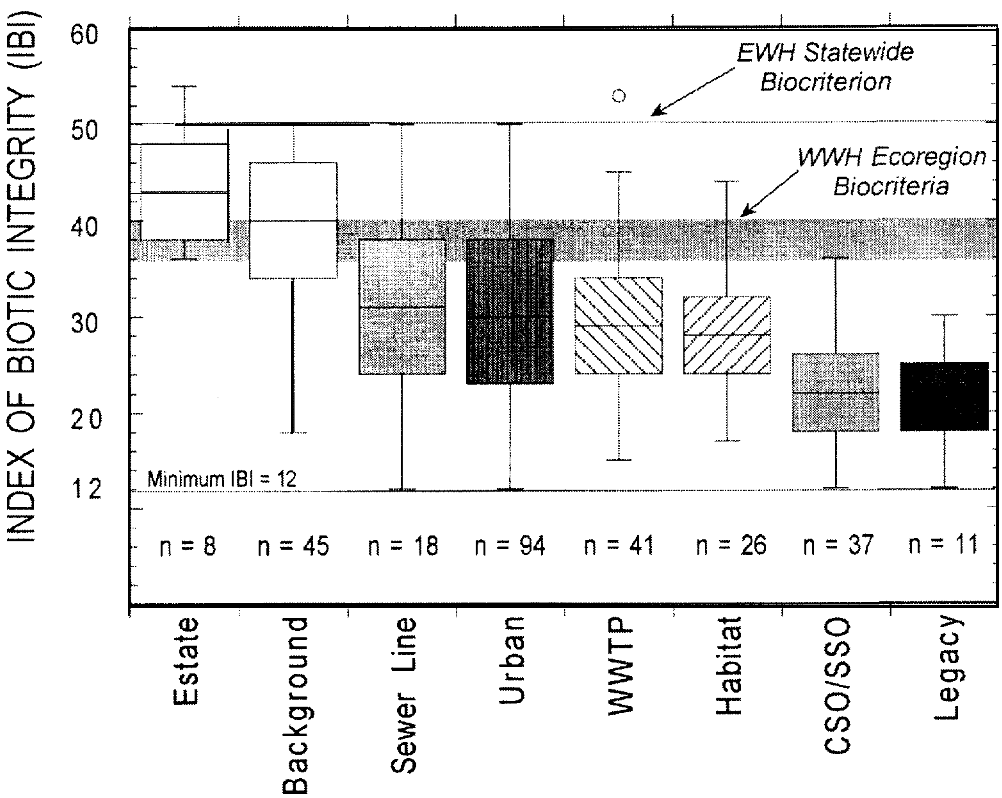


Figure 4. Distributions of Index of Biotic Integrity (IBI) from small streams (<50 mi.^{2}) in the six major metropolitan areas of Ohio plotted by quartiles of percent of urbanization upstream from sampling locations. Horizontal lines spanning adjacent box plots indicate similar means. Levels of percent of urbanization corresponding to the 25th, 50th and 75th percentile are indicated. The shaded areas indicate the applicable warmwater habitat biological criterion and the range of insignificant departure for the IBI.

Table 2. Analysis of Variance Results for the Anova Model, and the Ancova Model Using Qhei as a Covariate.

ANOVA Source	Sum-of-Squares	df	Mean-Square	F-ratio	P	R-Squared
Urban	4248.53	3	1416.18	27.50	0.0000	0.4094
Error	6129.10	119	51.51			
ANCOVA						
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P	
Urban	4020.66	3	1340.22	28.81	0.0000	
QHEI	640.71	1	640.71	13.78	0.0003	0.4711
Error	5488.39	118	46.51			

In an attempt to better visualize where attainment of warmwater habitat occurs along the urban land use gradient, the IBI results were plotted against percent of urban land use for all sites used in this study and with the other impact types excluded (Figure 5). The elimination of the other impact types provided for a more precise statistical relationship between urban land use and the IBI (i.e., lower error of regression estimates). For example, the R^2 was higher with the removal of the other impact types and the slope of the regression was steeper, both of which suggest a more meaningful relationship between the IBI and urban land use (Table 1). However, the percent of urban land use that corresponded to attainment of the warmwater habitat IBI biocriterion based on inspection of the scatter plot was the same (approximately 26%) in both plots.

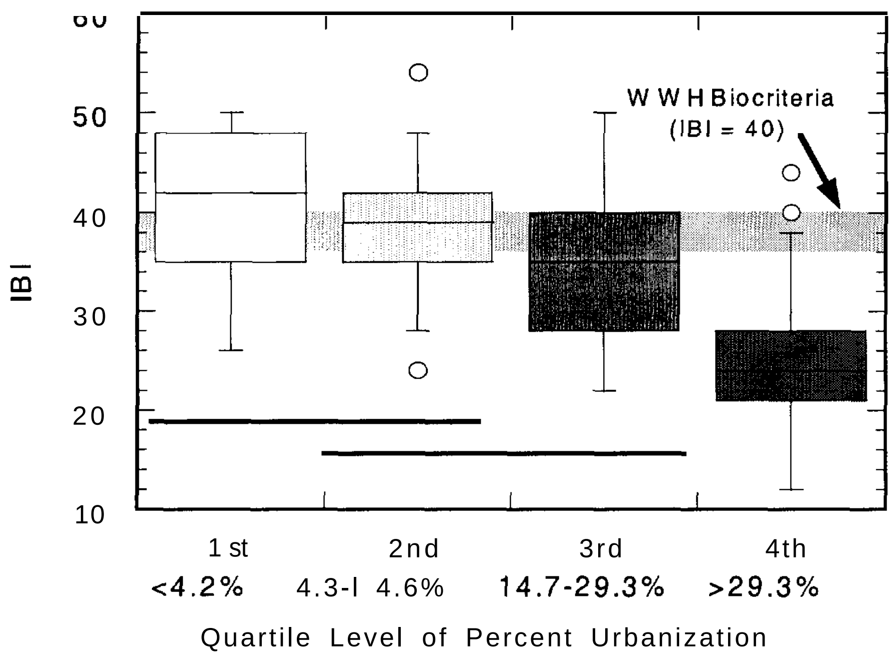


Figure 5. Scatter plots of Index of Biotic Integrity (IBI) scores against percentage of watershed upstream from the site in urban land use at small stream (<50 mi.[2]) sampling sites in six of the major metropolitan areas of Ohio for all sites (upper) and a subset with non-urban impact types removed (lower). The age of the urbanized area is indicated for selected sites and the mean and median age for entire dataset. The warmwater habitat biological criterion and the range of insignificant departure for the IBI are indicated.

Also apparent in both plots was the occurrence of "outliers" where IBI scores above the warmwater habitat biocriterion occurred at sites with 40% to 60% urban land use. These sites had either an intact, wooded riparian zone, a continuous influx of groundwater, and/or the relatively recent onset of urbanization. Intact riparian buffers can mitigate the effects of urban land use up to a point (Steedman 1988; Horner et al. 1997) and local hydrology can strongly influence the quality of the fish assemblage (Poff and Allen 1995). The three sites with the relatively recent onset of urbanization (all <20 years) may not yet have accrued the types of negative effects that are readily apparent in some of the older urbanized areas of Ohio.

Discussion

Threshold levels of urbanization beyond which biological communities are likely to be impaired have previously been identified in the range of 8% to 20% impervious cover within a watershed (Schuler 1994). Our previous analyses (Yoder et al. 1999) produced results of approximately 8% and 33% urban land use cover for the Cuyahoga River basin and Columbus area streams, as identified by analysis of variance. We also concluded that the threshold level identified by regression for the Cuyahoga River basin was lowered by the presence of other stressors (e.g., CSOs, point sources, legacy pollutants). The elimination of those sites impacted by these other stressorsfrom the regression analysis resulted in a higher threshold of urbanization. Our expanded study seemed to confirm this phenomenon, as the elimination of the other impact types helped clarify the urban land use/IBI relationship in a broader array of urban influenced streams throughout Ohio (Figure 5). The upper threshold of urbanization which corresponded to a loss of warmwater habitat attainment was in the 25-30% range. However, our results show that non-attainment also occurs at lower thresholds of urbanization (Figure 5) due primarily to the co-occurrence of other stressors. This makes both the linear and visual derivation of sufficiently precise indicator thresholds such as percentage of impervious surfaces more difficult.

In terms of understanding the potential effect of urbanization on aquatic life use attainment, the most meaningful results of our analyses are the upper thresholds at which attainment of CWA goal uses are mostly lost (e.g., 25%) and that beyond which it never occurs (>60%). Only a very few sites exhibited full attainment of the warmwater habitat biocriteria at urban land uses between 40-60% (Figure 5). A closer examination of these sites and the watersheds showed the presence of high quality riparian zones, an influx of flow augmenting groundwater, and/or development of the urban land use occurring within the past 20 years. For the latter, we hypothesized that the full effect of negative impacts in an urban setting may take time to accumulate and may not be immediately manifest in the form of instream impairments. This could account for the higher-than-expected urban land use (i.e., 40-60%) correlating with full attainment of the biocriteria. If this is true, then we might expect these sites to exhibit declines in IBI scores over the next one or two decades. It also suggests that newly urbanizing watersheds should be developed with an emphasis on determining which attributes (e.g., riparian zones, wetlands, flow regime) need to be maintained and preserved in order to protect and maintain instream habitat and biological quality.

The results of this study indicate that it might be possible to partially mitigate the negative effects of urbanization by preserving or enhancing near and instream habitats, particularly the quality of the riparian buffer zone. The "outlier" sites that exhibited full attainment of the warmwater habitat biocriteria had more extensive and higher quality riparian zones and good to excellent instream habitat quality. Some streams were nestled in small valleys which were not amenable to development and the accompanying encroachment of urban land uses. This generally agrees with the findings of Steedman (1988) who demonstrated a co-relationship between riparian zone quality and land use in terms of how each affected the fish communities and IBI values of Toronto area streams. Horner et al. (1997) also found that the negative effects of urban land use were mitigated by riparian protection and other management interventions. However, in both studies the quality and extent of the riparian zone ceased to be effective above 45-60% impervious land cover, which generally corresponds to the thresholds identified by our study. Until we better understand the effect of the "age" of the urban effect, it seems prudent to advocate policies that preserve existing riparian zones rather than responding with post-urbanization retrofits.

Yoder et al. (1999) discussed the implications of their findings on the designation of aquatic life uses in state water quality standards, particularly to the use attainability analysis process. Uses designated for specific water bodies are done so with the expectation that the criteria associated with the use are reasonably attainable. If CWA goal uses (e.g., warmwater habitat in Ohio) are found to be unattainable, then lower quality uses may be established and assigned on a case-by-case basis (40CFR, Part 131 .10[g]). Recently, the imperviousness of the watershed has been suggested as an indicator that is correlated with use attainability. If the frequently cited threshold of 25% impermeability is used, streams in watersheds with greater than this value could be considered unlikely to ever attain a beneficial use regardless of site- and reach-specific factors. This assumes that the negative effects of urbanization cannot be remediated, which has yet to be extensively tested. However, the results of our study suggest that there is a threshold of watershed urbanization (e.g., >60%) beyond which attainment of the WWH use becomes increasingly unlikely, at least as affected by contemporary practices. This threshold is not the same in all watersheds, as evidenced by the results from the six Ohio metropolitan areas, and it can occupy a rather wide range. In addition, co-factors such as pollutant loadings, watershed development history, chemical stressors, and watershed scale influences such as the quality of the riparian buffer and the mosaic of different types of land use, also act singly and in combination to determine to the resultant biological quality in the receiving streams. Thus, single dimensional urban land use indicators, such as watershed imperviousness, is not sufficiently precise or reliable as a single indicator of use attainability.

The further development and refinement of multiple indicators of watershed urbanization has merit from a management and decision-making standpoint. Because of the many co-factors involved (e.g., water quality, habitat quality, hydrologic regime, etc.), some of which are controllable and amenable to reasonable remediation, this will be a complex undertaking. We suggest that these co-factors, in addition to more refined urban land use indicators, be developed and tested using datasets from broad geographic areas spanning the extremes of the urbanization gradient. Urban land use and its analogs (e.g., % imperviousness) are coarse approximations of the cumulative effect of all negative influences within a watershed. Thus co-factors and more precise definitions of different urban land uses need to be defined in order to better understand and respond to the water quality management challenges posed in existing and developing urban areas.

A management outgrowth of such an effort could be the development of an urban stream habitat use designation. Yoder et al. (1999) previously indicated where the biological criteria for this potential new use designation might occur compared to the already existing hierarchy of aquatic life uses in the Ohio WQS (Figure 6). This designated use would

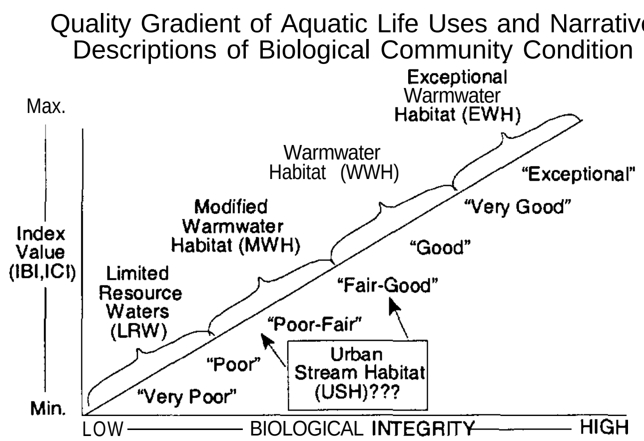


Figure 6. Relationship between the tiered aquatic life uses in the Ohio WQS and narrative evaluations of biological community performance and how this corresponds to a qualitative scale of biological integrity and of the biological indices that comprise the Ohio biological criteria. The position of a potential new Urban Stream Habitat (USH) use designation is indicated (after Yoder et al. 1999).

satisfy the desire to afford urban streams the maximum protection practicable, while recognizing the inherent limitations that the irretrievable effects of urbanization may impose on stream quality. In the meantime, simplistic regulatory and management approaches should be avoided, particularly in those watersheds where uncertainty about the attainability of CWA goal uses (i.e., WWH and higher) exists. For example, a single indicator of urban development (e.g., proportion of impermeable surfaces) is alone insufficient to drive this process. We envision that more refined, multiple indicators of urban development will provide the necessary sophistication to more appropriately define when this less than CWA goal use should be applied. In the meantime, management strategies such as the nine minimum controls for CSOs seem reasonable analogies for the management of urban watersheds and stormwater runoff. However, proceeding beyond such minimum requirements with long-term remediation plans should be done with deference to the use attainability issues and with the aid of sufficiently robust before-and-after biological and water quality assessments.

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Getting Past the Obvious

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Abstract

Long Leaf Creek is located within an urbanized watershed along coastal North Carolina. The specific stream reach addressed is located in a residential subdivision. Conditions had dramatically changed there due to the continued development of the watershed. The stream had deepened and widened as result of increased runoff and high concentration events, including hurricanes. This increased the loss of aesthetic value, riparian corridor vegetation, and aquatic and terrestrial habitats. Water quality was also degraded.

Before they could decide how best to control flooding and stabilize and restore Long Leaf Creek to a naturally functioning channel within its changed watershed conditions, citizens had to be educated about natural stabilization and restoration technologies and specificmethods that would work, including conventional options. Soil bioengineering was agreed upon, with numerous modifications to meet specific needs.

This paper is presented from both the client's and consultant's perspectives. It identifies what worked, what did not work, and what was necessary to improve the process for successful, long-term results. We present the lessons learned from criteria issue development and understanding, educational process alternatives preparation, design, construction, and project results since construction.

Paper

Long Leaf Creek is located within an urbanized watershed along coastal North Carolina. The specific stream reach addressed is approximately 2000 feet in length and is located in a residential subdivision. It is a highly sensitive project with a variety of multi-objective goals specific to its location and function and typical to urbanizing areas. The watershed includes residential, office, institutional, and commercial properties, including 25 homes that line the creek in this area. Residents living along the creek described the former Long Leaf, as a small, picturesque stream that pleasantly flowed through their neighborhood--a stream that could be jumped across. It was enjoyed by many people. The conditions had dramatically changed, however, due to the continued development of the watershed, especially a new road and large shopping center immediately upstream. Residents have seen their stream deepen by almost ten feet and widen by 40 feet in areas, a result of increased runoff and high concentration events, including hurricanes. In many areas, the banks were vertical. Large, woody debris filled much of the channel, and many people were now using the "ditch" as a yard and construction waste dump (see Figure 1). This has resulted in increased the loss of aesthetic value, riparian corridor vegetation, and aquatic and terrestrial habitats. Water quality has also been degraded.

Many people had already lost property due to stream widening and were unwilling to lose more. Flooding was a major problem in the downstream end, while erosion was occurring throughout the project reach. The City of Wilmington was interested in exploring a natural approach to solving the problem. After assessing the site and conditions, and listening to the residents= concerns and desired solutions, it was clear that a strong, continual working relationship had to be formed with the neighborhood to ensure project success.

Figure 1. Pre-Construction Conditions

Before they could decide how best to control flooding and stabilize and restore Long Leaf Creek to a naturally functioning channel within its changed watershed conditions, citizens had to be educated about natural stabilization and restoration technologies and the specific methods that would work, including comparative conventional options. To “get past the obvious,” it was clear that almost everyone would have to give up some land and existing trees to solve their continued land loss and flooding problems and to improve the environmental and aesthetic values of Long Leaf Creek. How much land and how many trees they would lose would ultimately depend on their selected restoration alternative. A matrix was developed using critical issues and matching these to possible alternatives (Table 1). Soil bioengineering was agreed upon, with numerous modifications to meet specific needs.

Robbin B. Sotir & Associates, Inc., (RBSA), served as the soil bioengineering consultant to the prime, the Kimley-Horn’s interdisciplinary team, developed the geotechnical design and hydraulic eff iciencies of a soil bioengineering solution to address the desired goals and critical engineering, environmental, and aesthetic issues.

Alternatives were compared with such critical issues as erosion control, streambank stabilization, safer and healthier environment, flood control, timely project completion, environmental and aesthetic improvement, property loss minimization, hydraulic efficiency, and cost feasibility.

After an initial investigation, an alternative analysis was produced in the summer of 1997. This alternative analysis explored numerous approaches to solving each of the project goals, with cost and risk factors assigned to each alternative. Several alternatives were considered, such as box culverts, 3:1 (horizontal : vertical) grassed slopes, 2:1 riprap rock, 2:1 concrete lining, and soil bioengineered slope systems. With input from the residents and permit authorities, the City selected the soil bioengineering approach and commissioned a design team to produce plan and specification documents, including construction cost estimates.

The selected systems employed the use of live fascines, brushlayer/live fascines, joint planting and vegetated geogrids (see Figures 2 through 5).

The majority of the improvement was done using vegetated geogrid, due to its soil reinforcing capabilities and ability to reduce land losses (see Figure 6).

Pre-bid, preconstruction, and permit application services were provided to support the project. Construction was completed by the spring of 1999.

The project has performed well from a biological perspective. Willow, baccharis, and myrtle installed as cuttings in the lower layer had a survival rate of approximately 80%. The rooted stock installed in the upper two layers comprised of spirea bush, Carolina allspice, serviceberry, and viburnum, were less successful, with a survival rate of approximately 60% due to an insect infestation (see Figure 7). Hydraulically, we have had some bed scour, accompanied by toe erosion.

The survival rate of the rooted stock would have been higher had the watering maintenance program been followed. It is also possible that the insect infestation would not have occurred if the plants had been kept healthier by better maintenance practices. The rooted plants will be replaced by the contractor under the maintenance agreement. The contractor is also responsible for taking care of the insect infestation. The bed scour in the upper level caused by Hurricane Floyd is being handled with check dams to stop the bank from lowering and to control the toe scour.

Table 1. Long Leaf Hills/Hewletts Creek Alternatives and Critical Issues

Critical Issues	Alternatives: Intermediate Action	3:1 Side Slopes Grass Lining'	2:1 Side Slopes Riprap Rock'	2:1 Side Slopes with Concrete Lining*	Reinforced Box Concrete	Soil Bioengineering
Stop Erosion & Stabilize Banks		●	●	●	n/a	●
Clean Out Trash & Debris, Remove Fallen Trees	●	●	●	●	●	●
Safer & Healthier Area		●				●
Control Flooding		●		●	●	●
Timely Project Completion	●	●		●	●	●
Environmental Improvement		●			●	●
Aesthetically Enhancing		●			n/a	●
Meets Hydraulic		●		●	n/a	●
COE and Environmental Permits Approval Probability	●					●
Minimize Property Loss	●				●	●
Preliminary Cost Estimate Range	$250,000 to $400,000	$640,000 to $800,000	$900,000 to $1,400,000	$785,000 to $1,200,000	$1,750,000 to $2,300,000	$1 ,000,000 to $1,300,000

'Does not address geotechnical issues of sandy bank material stability and major land loss requirements.
*Does not address increased safety concerns or reduction in property values.

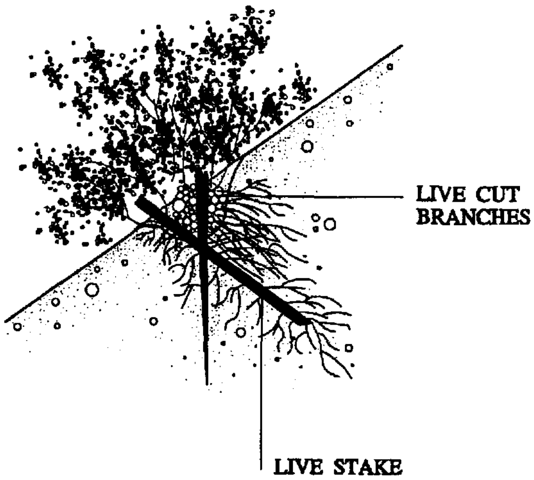

Figure 2. Live Fascine.

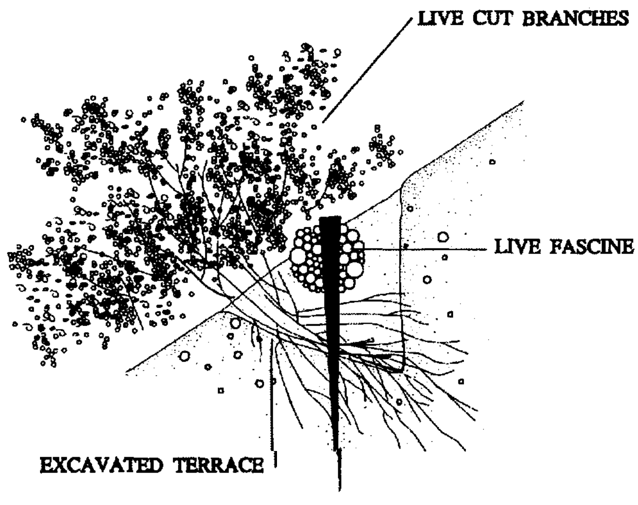

Figure 3. Brushlayer/Live Fascine.

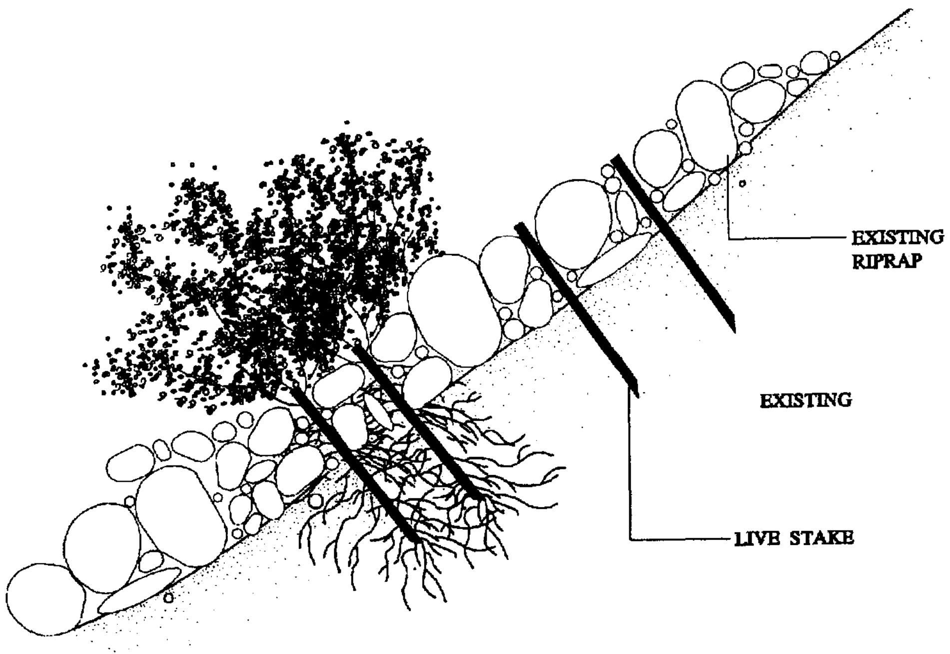

Figure 4. Joint Planting.

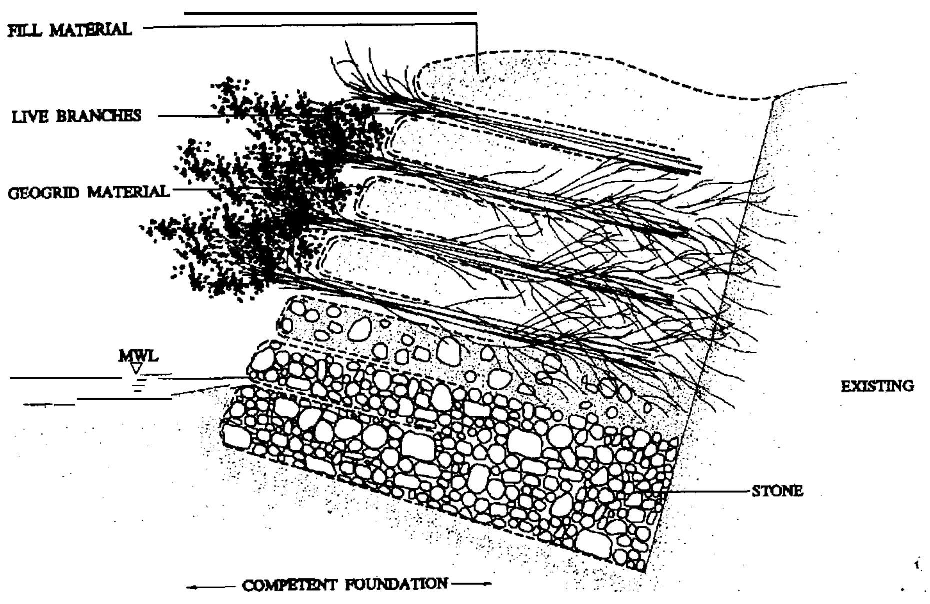

Figure 5. Vegetated Geogri

Figure 6. During Construction.

Figure 7. Three Months After Construction.

The project is functioning well from the bank stability and flood control aspects and the stream is operating within the parameters of the new watershed conditions. It is aesthetically attractive and, over time, should develop some ecological diversity. In summary, it is clear that the soil bioengineering approach is succeeding. The most important lessons learned were as follows:

- Learn more about the bed conditions in areas that have had high deposits of mobile materials
- Employ sophisticated grade control structures
- Ensure installation procedures are followed correctly and that materials are not changed
- Keep tabs on the contractor's maintenance schedule
- There is no substitute for communication and cooperation

Reference

Sotir, R.B.; "Brushing Up On Erosion," American Cities and Counties, February, 1998.

Protecting and Enhancing Urban Waters: Using All the Tools Successfully

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Abstract

Reducing the hydrologic effects and pollutant loadings from urban drainage systems and restoring aquatic habitats to improve the health of our aquatic ecosystems presents many unique challenges. These challenges can be categorized as technical, institutional, financial, and cultural. This paper will examine each of the challenges and the tools that have and are being developed to overcome them. A case study on how the tools are being used in Florida to enhance the health of the Tampa Bay aquatic ecosystem will be presented.

Introduction

Research conducted in Florida during the late 1970s characterized stormwater pollutants, provided cost and benefit information on many types of stormwater treatment practices, and determined the importance of stormwater discharges as a major source of pollution. As a result, in 1979, the Florida Environmental Regulation Commission adopted the state's first stormwater treatment requirements. In 1982, the state's stormwater rule was fully adopted, requiring all new development and redevelopment projects to include site appropriate BMPs to treat stormwater. This technology-based program establishes a performance standard of removing at least 80% of the average annual post-development loading of total suspended solids for stormwater discharged to most waters. Stormwater discharges to the state's most pristine waters, known as Outstanding Florida Waters, are required to reduce pollutant loading by 95%.

Florida's stormwater treatment program, in combination with the state's wetlands protection, land acquisition, and growth management programs, has greatly minimized the effects of Florida's rapid growth on its water bodies. However, land uses and hydrologic alterations that occurred before the mid-l 980s has continued to adversely affect the state's vulnerable and valuable aquatic ecosystems. Accordingly, the focus of Florida's watershed management program shifted to cleaning up "older sources" such as existing land uses, whether urban or agricultural, and to integrating program components to eliminate duplication and improve efficiency and effectiveness. This has led to greater emphasis on more holistic approaches to address cumulative effects of land use activities within a watershed and to a greater emphasis on regional structural controls and the purchase or restoration of environmentally sensitive lands. The key institutional components of this watershed approach have been described in detail (WMI, 1997; Livingston et al., 1995).

Development of Florida's Watershed Assessment Tools

Florida's Water Implementation Rule, Chapter 62-40, F.A.C., establishes a performance standard for reducing, on a watershed basis, the pollutant loading from older stormwater systems. The goal is to protect, maintain or restore the beneficial uses of the receiving water body. The amount of needed pollutant load reduction is known as a "Pollutant Load Reduction Goal or PLRG". The rule further specifies that PLRGs be established as part of the states's priority watershed program, Surface Water Improvement and Management (SWIM), which is implemented by the state's five water management districts. Consequently, stormwater PLRGs have *been* established for several water bodies leading to the development and implementation of watershed plans to reduce pollutants from urban and agricultural stormwater discharges. For example, farms within the Everglades Agricultural Area have implemented BMPs to reduce phosphorus loadings by 40%. Additionally, the federal and state government, SFWMD, and landowners within the EAA are sharing the cost of constructing tens of thousands of acres of wetlands (Stormwater Treatment Areas) to provide for additional reduction of phosphorus.

Having a sound institutional framework, however, is only one of the tools needed to successfully reduce stormwater pollutant loadings from existing land uses. Equally important are funding and public education to promote the cultural change necessary to reduce “Pointless Personal Pollution”. A final cornerstone is good science -to establish ecologically meaningful watershed management goals, evaluate the effectiveness of BMPs and management programs, and assess the cumulative effects of wet weather discharges.

Unlike traditional point sources of pollution, the effluent quality and environmental effects of stormwater and other nonpoint sources of pollution are highly variable because of their intermittent, diffuse, land use-specific nature. Of particular environmental concern is the cumulative impact on a water body from the numerous stormwater/nonpoint sources within a watershed. Consequently, traditional water quality monitoring and management efforts used for point discharges generally suffer from several deficiencies when trying to understand and manage stormwater/NPS pollution. These deficiencies include difficulty in:

1. Assessing intermittent, shock loadings of pollutants.

2. Assessing cumulative impacts of multiple sources.

3. Comparing water bodies and establishing priorities for management actions.

4. Assessing hydrologic, geomorphological, and habitat alterations within a watershed.

5. Distinguishing actual or potential problems from perceived problems.

6. Discriminating anthropogenic loadings from natural watershed loadings of metals and nutrients.

7. Establishing cost-effective ways to assess pollution sources and trends on a watershed basis.

To overcome these problems, the Florida Department of Environmental Protection (DEP) has developed cost-effective sediment and biological monitoring tools that are much better suited for assessing cumulative effects than traditional water chemistry monitoring (Livingston et. al, 1995; McCarron et al., 1997). Most stormwater pollutants accumulate over time in sediments, not the water column. Therefore, the sediments and the organisms that reside in them offer an in-situ monitoring opportunity to determine the cumulative effects of watershed stormwater/NPS pollution sources on aquatic systems or to evaluate the effectiveness of management programs.

Sediment quality is a sensitive indicator of overall environmental quality. Sediments influence the environmental fate of many toxic and bioaccumulative substances in aquatic ecosystems (Long and Morgan, 1990). Sediments tend to integrate contaminant concentrations over time and may represent long-term sources of contamination. Specifically, sediment quality is important because many toxic contaminants found in only trace amounts in water can accumulate to elevated levels in sediments. Sediment-associated contaminants can also directly affect benthic and other sediment-associated organisms since sediments provide benthic and pelagic communities suitable habitats for essential biological processes (e.g. spawning, incubation, rearing, etc.).

Sediments provide an essential link between chemical and biological processes. By understanding this link, environmental scientists can develop assessment tools and conduct monitoring programs to more rapidly and accurately evaluate the health of aquatic systems (Pardue et al., 1992). Therefore, sediment quality data provide essential information for evaluating ambient environmental quality conditions in water bodies. Additionally, information about the amount and quality of sediments within stormwater systems, stormsewers and other stormwater conveyances can help trace pollution sources, prioritize areas for implementing control measures, and help to assure proper disposal of accumulated sediments.

Inclusion of biological community monitoring allows a more holistic, systems approach that greatly enhances surface water quality assessment and management (Yoder, 1989; Yoder and Rankin, 1997). In particular, it allows assessment of the degradation of habitat (e.g., channel and bank erosion) and siltation within water bodies, neither of which are detected by water chemistry sampling, and both of which are typically associated with wet weather discharges. While chemical data reflect short-term conditions that exist when a particular sample is collected, biological communities accurately indicate overall environmental health because they continuously inhabit receiving waters where they integrate a variety of environmental influences - chemical, physical and biological.

Biological assessment involves an integrated analysis of functional and structural components of aquaticcommunities (Karr and Dudley, 1981; Karr, 1991). Bioassessments are best used to detect aquatic life impairments and assess their relative severity. Once an impairment is detected, additional chemical and biological toxicity testing can identify the causative agent and its source. Both biological and chemical methods play critical roles in successful pollution control and environmental management programs. They are complementary, not mutually exclusive, approaches that enhance overall program effectiveness.

A fundamental part of bioassessments is "metrics" (Karr and Chu, 1998). Just as a doctor uses metrics such as blood pressure and heart rate to assess human health, biological metrics allow the ecologist to use meaningful indicator attributes to assess the status of communities in response to perturbation. The definition of a metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al., in review). By using multiple metrics to assess biological condition, the information available about the elements and processes of aquatic communities is maximized. The validity of an integrated assessment using multiple metrics is supported by the use of measurements of biological attributes firmly rooted in sound ecological principles (Fausch et al. 1990; Lyons 1992).

In 1983, the DEP began developing assessment tools that could be used to assess stormwater and NPS effects and the effectiveness of management programs, practices, and activities. The first efforts focused on estuarine sediment assessment tools (FDER, 1988; Schropp et al., 1989, 1990; MacDonald, 1994). In 1989, efforts began to modify national bioassessment protocols (EPA, 1989) to develop quantitative bioassessment protocols for Florida (Griffith et al., 1994; Barbour et al., 1996, FDEP, 1996). The tools that have been developed and that are under development (noted by a *) include:

A. Sediment assessment tools

1. Standardized sediment collection and analysis protocols.
2. Estuarine normalization of metal concentrations to aluminum concentrations ratio.
3. Estuarine sediment quality assessment guidelines
4. Freshwater normalization of metal concentrations to aluminum concentrations ratio(*).
5. Freshwater sediment quality assessment guidelines(*).

B. Bioassessment tools:

1. Stream Condition Index
2. Lake Condition Index (* - nearly completed)
3. Wetland bioassessment methods (* - in early stages of development)
4. Canal bioassessment methods (* - in middle stages of development)
5. Estuarine bioassessment methods (* - in early stages of development)

Using the Tools for Watershed Management

Sediment assessment, together with watershed characterization, future land use plans, stormwater master plans, and mapping of pollution sources, can be used to screen watersheds and sub-basins to determine potential "hot spots".

Bioassessment and water chemistry sampling can then be done to assess the actual health of the aquatic system in these locations. An important component of the bioassessment is habitat quality, especially since urbanization often leads to dramatic changes in stream hydrology, geomorphology, riparian zones, habitats, and ultimately biological communities. Possible outcomes of the bioassessment are: (1) no biological effects; (2) effects due to habitat degradation; (3) effects due to sediment or water quality; or (4) effects due to a combination of sediment, water quality and habitat degradation. Bioasssessments also allow the establishment of an ecologically-based aquatic resource goal, rather than one based solely on traditional water chemistry standards to which the applicability to wet weather discharges is questionable. Once an aquatic resource goal is established, then relationships between the needs of the biological community and the chemical, sediment, and habitat influences on the community can be established. The next step is to then use all of this information to develop a watershed management plan that includes specific projects, schedules, and funding sources that will ultimately result in the acheivement of the desired aquatic ecological goal. Much of this effort can be coordinated and implemented using the rotating basin approach that many states are now using in combination with the NPDES stormwater permitting program.

Putting the Puzzle Pieces Together: Tampa Bay Case Study

Puzzle Piece *1:* The *Assessment*- As part of the development of the Tampa Bay SWIM Plan (SWFWMD, 1992) and the Tampa Bay NEP Comprehensive Conservation and Management Plan (TBNEP, 1996), existing environmental information was assessed to determine the ecological health of the bay system. Major findings of these assessments are summarized below.

Habitats

1. Since 1950, about half of the bay's natural shoreline and 40% of its seagrasses have been destroyed.

2. In 1950, the bay's shallow shelf supported about 40,000 acres of seagrasses. By 1982, only 21,600 acres remained and virtually all of Hillsborough Bay's 2,700 acres were gone. Seagrass decline is due to dredging and filling for residential development, turbidity caused by dredging of the main shipping channel, and reduced light penetration caused by shading by algae fueled by excess nutrient discharges.

3. Since the early 1900s approximately 13,200 acres of bay bottom (3.6% of the bay's surface area) were filled, with over 90% of the activity occurring along the bay's shallow shelf where seagrasses once thrived. The surface area of Hillsborough Bay has been reduced by 14%.

4. Upgrading sewage plants in the 1980s to provide advanced wastewater treatment reduced nitrogen loadings, leading to a decline in phytoplankton, an increase in water clarity, and greater light penetration. Consequently, between 1982 and 1992 seagrass coverage increased by about 4,000 acres (18.5%) raising the bay's total acreage to over 25,600 acres.

5. About 43% (9,700 acres) of Tampa Bay's original saltwater wetlands were lost between 1950 and 1990, primarily because of dredging and filling for waterfront development. However, as many as 5,900 acres of new wetlands formed along causeways and other emergent land created by dredged spoil material during this period. Recent estimates of wetland habitat in Tampa Bay indicate that about 18,000 acres of mangroves and saltmarsh remain but many thousands of acres are damaged by invasion by exotic plants such as Brazilian pepper.

Fish and Wildlife

1. Between 1966 and 1990, the harvest of 11 commercial species of fish declined by 24%, primarily because of smaller catches of mullet and sea trout. Each of these species is dependent on seagrass habitats.

2. Harvest of spotted sea trout declined by 86% between 1950 and 1990, from 487,000 pounds to 67,000 pounds. Similarly, red drum harvests plummeted from 80,000 pounds in 1950 to 15,000 pounds in 1986.

3. Tampa Bay's once-thriving shellfish industry has virtually collapsed, except for bait shrimping. Harvests of clams or oysters are restricted or prohibited throughout the bay because of high bacterial levels associated with stormwater discharges and septic tanks. The bay scallop, a highly pollution sensitive organism, all but disappeared from the bay in the 1960s.

Water and Sediment Quality

1. While water quality has improved over the past ten years, primarily as a result of better wastewater treatment, water clarity, nutrients, and toxics continue to be a problem.

2. Because of natural circulation and flushing from the Gulf of Mexico water clarity is greatest in the lower part of Tampa Bay (2.5 m), and naturally decreases moving up the bay, dropping to an average of 2 meters (6.6 feet) in Middle Tampa Bay and Old Tampa Bay. The lowest average water clarity is in Hillsborough Bay (1.5 m) which has poor circulation and receives a larger share of nutrients and sediments from major rivers.

3. Excessive amounts of nitrogen continue to accelerate algal growth which subsequently reduces light penetration to seagrasses and contributes to oxygen depletion. The bay's total annual nitrogen load was estimated to be 2.5 times greater in 1976 than the load computed for 1985 to 1991 (Figure 1).

4. Recent studies by NOAA, in cooperation with FDEP, provide an excellent overview of the levels and distribution of toxics in bay sediments (Long, et. al. 1991, 1994; FDEP, 1994). Compared to other urban estuaries, Tampa Bay has low-to-moderate levels of most toxic parameters. Contamination is centered around large urban centers, ports and marinas, and concentrations generally decrease from the top of the bay toward the Gulf of Mexico.

5. Generally, the highest levels of sediment toxic contamination occur in Hillsborough Bay, the bay's most industrialized area and home to the state's busiest port. Upper Hillsborough Bay has the highest levels of cadmium, copper, mercury, zinc, and lead, as well as the pesticide DDT. Concentrations in sediments at a site in northern Hillsborough Bay were the highest of any toxic pollutant measured in Tampa Bay. Two other bays with heavily urbanized watersheds, Boca Ciega Bay and Bayboro Harbor, also can be considered as hot spots of toxic contamination.

6. Figure 2 shows sites in Tampa Bay where concentrations of toxic contaminants in sediments exceeded Florida's Probable Effects Level (PEL) and No Observable Effects Level (NOEL). Sites above the PEL indicate a high probability for biological impact to marine organisms while those above the NOEL are considered "at risk" to biological impact (MacDonald, 1994).

Puzzle Piece 2: *The* Goal: A critical component of watershed management is using biological living resources as a measure of a water body's health, with far less emphasis on traditional laboratory-based water quality standards. This approach addresses critical ecological effects that are not seen by water chemistry standards, allows greater flexibility to achieve the desired ecological goals, and provides taxpayers with a better benchmark to judge the return on their expenditures. Through the SWIM Plan and the Tampa Bay NEP CCMP, the primary overall goals have been established for the restoration and protection of Tampa Bay:

1. To reverse the environmental degradation of the Tampa Bay estuarine system.

2. To optimize water quality and other habitat values, thereby promoting the sustained existence or re-establishment of thriving, integrated, biological communities.

3. To ensure the maintenance of a productive, balanced ecosystem complimentary with human needs and uses of the resources.

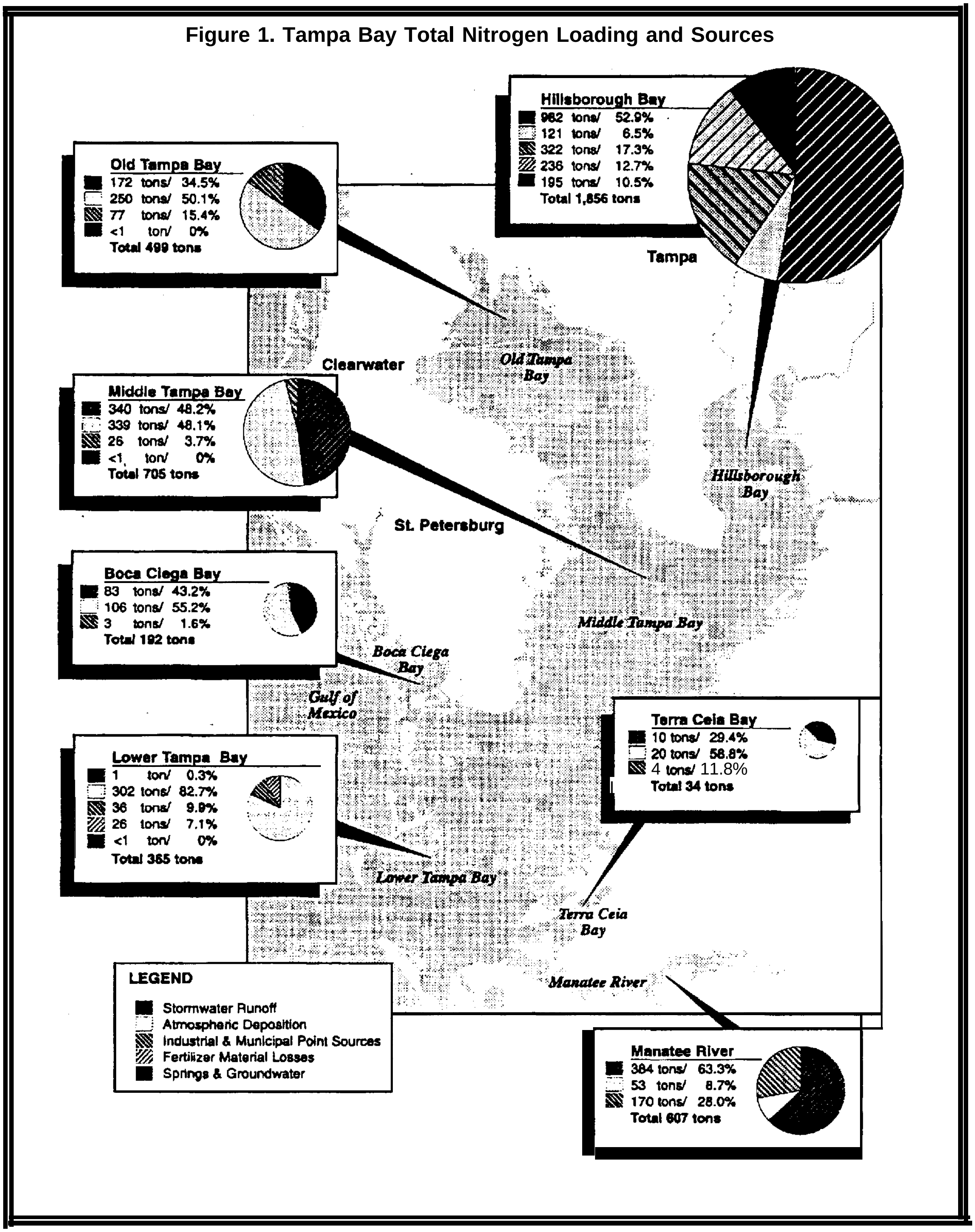

Figure 1. Tampa Bay Total Nitrogen Loading and Sources.

Figure 2. Sediment Toxic Hot Spots in Tampa Bay

Figure 2 shows sites in Tampa Bay where concentrations of toxic contaminants in sediments have exceeded Florida's Probable Effects Level (PEL) and No Observable Effects Level (NOEL) for biological impact. Sites registering above the PEL indicate that some biological impact to marine organisms is likely. Sites registering above the NOEL are "at risk" to biological impact.

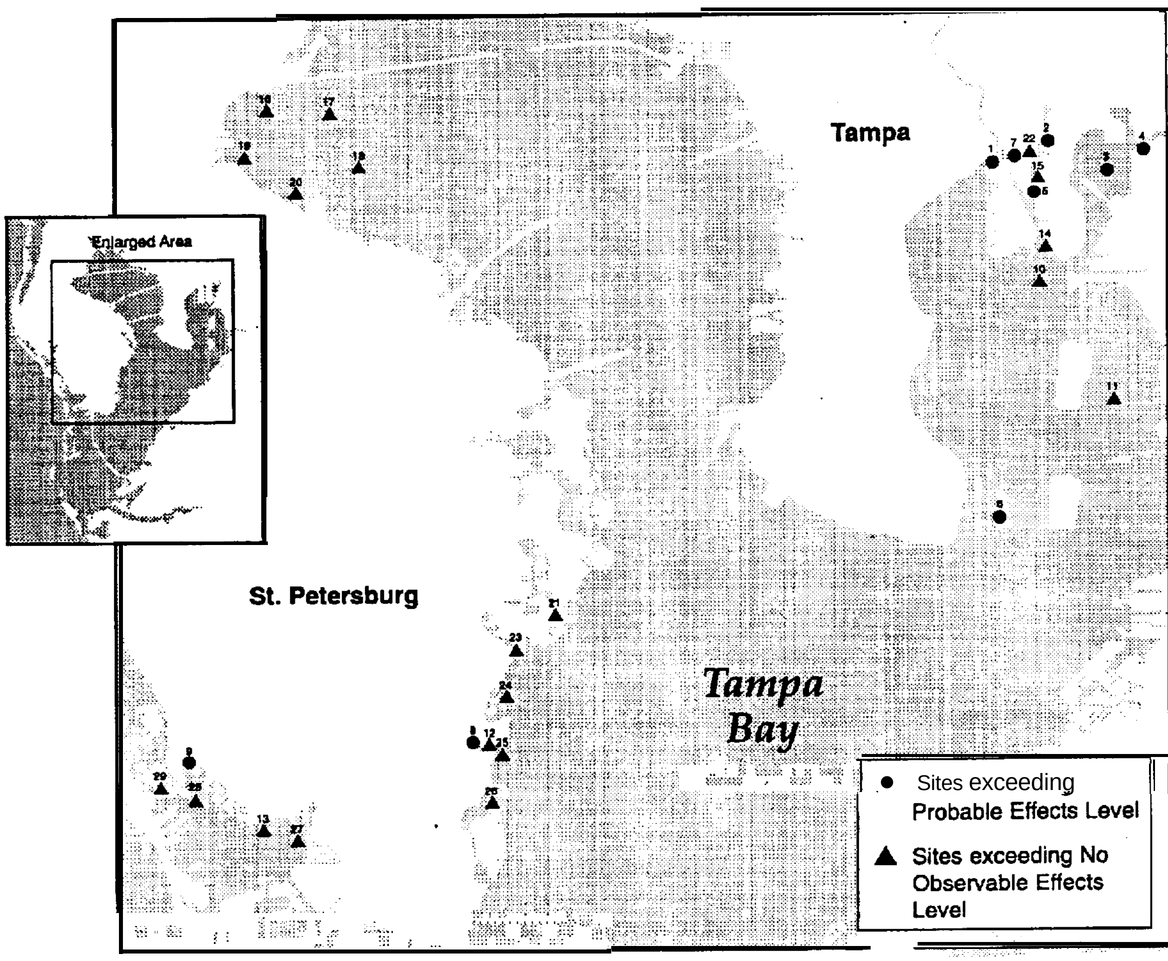

Figure 2. Sediment Toxic Hot Spots in Tampa Bay.

To achieve these overall goals the following specific goals have been established:

1. The overall goal is to restore seagrasses to 1950s levels. This will lead to restoration of commercially important species such as the bay scallop, mullet, sea trout, and red drum.

2. To restore seagrasses to 14,000 acres of the bay. The ability of seagrasses to recolonize the bay depends on the amount of sunlight the grass species require, as well as shading factors such as the amount of drift macro-algae and attached algal growth on grass blades. For most seagrasses in the bay, an estimated 20% to 25% of the light striking the bay's surface must penetrate to target depths to allow seagrass regrowth. Reducing nitrogen loadings will reduce chlorophyll a concentrations thereby increasing the depth of sunlight penetration.

3. As many as 12,000 acres of seagrass can be recovered by maintaining recent water quality conditions. This will require local communities to reduce their nitrogen loadings to the bay by about 10% by the year 2010 to compensate for increases in nitrogen loadings associated with the watershed's population growth.

4. A coastal habitat master plan has been developed for the watershed that will help to coordinate and prioritize existing state, regional, and local restoration programs. The long term goal is to recover 1,800 acres of low-salinity tidal marshes while maintaining and enhancing salt marshes and mangroves at existing levels. A minimum goal is to restore 100 acres of tidal marsh habitat every five years.

5. Reduce sediment toxicity to minimize risks to marine life and humans. Using three tests -evaluation of sediment chemistry, sediment toxicity, and benthic community health - bay sediments will be characterized and prioritized for management.

6. Reduce bacterial contamination to levels safe for swimming and shellfish harvesting.

Puzzle Piece 3: The *PLRG:* To achieve the ecological goal, nitrogen loadings would need to be held to those occurring in 1992-94 meaning that the 17 tons of nitrogen loading that would accompany projected growth within the watershed would have to be compensated. Reduction of nitrogen would reduce chlorophyll a levels which would increase how deep the minimum levels of light needed for seagrass growth would penetrate the water column.

Puzzle Piece 4: Quantifying Pollution Sources: Before load reductions can be achieved, it is essential that the sources and relative contribution of the sources be quantified.

Figure 3 summarizes sources of nonpoint nitrogen loadings to Tampa Bay.

1. Stormwater runoff from the Tampa Bay watershed contributes about 47% of the bay's total annual nitrogen load with urban runoff accounting for about 16%, or 680 tons. Residential areas, the watershed's largest land use, is responsible for over half of the nitrogen loading while commercial/industrial sites account for about 20%.

2. About 28% of the bay's total nitrogen loadings, or 1,200 tons, are from atmospheric pollutants falling directly on the water. An additional 7,500 tons fall in the watershed, although no one can determine how much enters the bay via stormwater. EPA estimates that as much as 67% of the bay's total nitrogen load may be from the atmosphere.

3. Stationary sources, primarily power plants, contribute an estimated 50% of the anthropogenic NO, emissions as compared to 35% from motor vehicles.

4. Domestic wastewater discharges still discharge about 8% (340 tons) of the bay's total annual nitrogen loadings, even though all plants provide AWT. Hillsborough Bay receives about two-thirds of the cumulative nitrogen load from the 36 billion gallons of effluent discharged to Tampa Bay each day.

5. Industrial wastewater discharges, primarily fertilizer manufacturing and shipping facilities, are responsible for about 6% of the bay's total annual nitrogen loadings.

Figure 3. Total Nitrogen Loadings

Per-Acre Nitrogen Loadings from Non-Point Sources

	% Loading	% Watershed	Yield lbs/ac/yr
Ruidential	11	15.5	4.52
Commercial Industrial/Institutional	5	6.4	5.26
Mining	4	3.2	4.97
Range and Pasture	13	20.4	2.81
Intensive Agriculture	6	6.5	5.63
Undeveloped Land	8	39.93	1.15

Total Nitrogen Loadings to Tampa Bay (1882-1994 average)

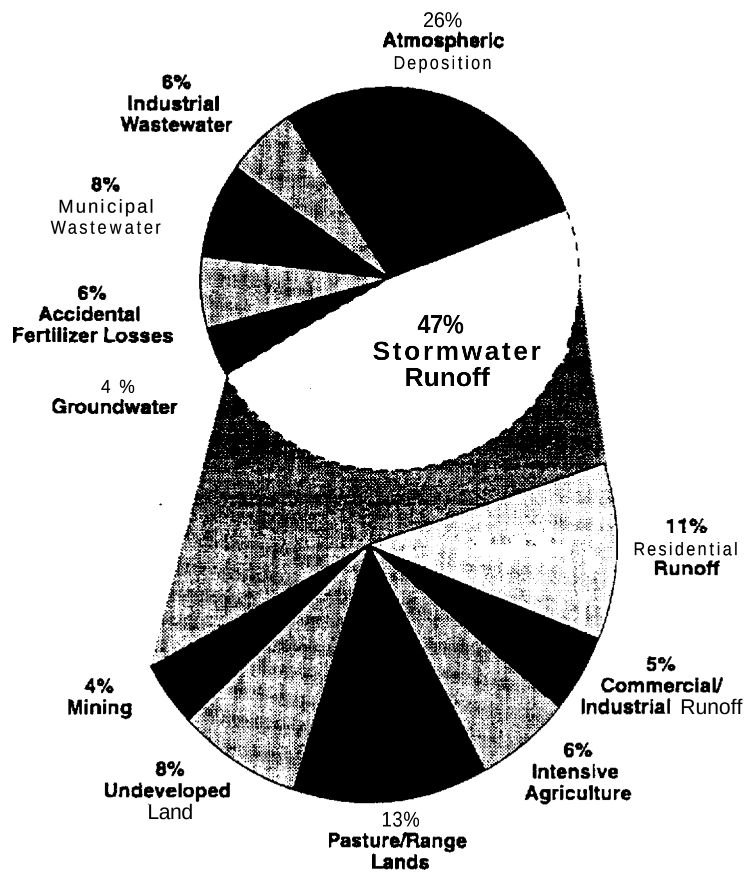

Figure 3. Total Nitrogen Loadings.

6. Septic tanks, which serve about 20% of the watershed's population, are another important source of nitrogen and pathogen loadings, especially in some areas such as Allen's Creek and tributaries to McKay Bay.

7. Another 7% of the bay's total nitrogen loadings had been attributed to losses of fertilizer during ship loading and en route to port. However, this figure has declined substantially since 1991 as source control BMPs were implemented at the port.

8. More than 60% of the bay's annual loadings of chromium, zinc, mercury and lead, as well as significant amounts of petroleum hydrocarbons and pesticides are conveyed by stormwater.

9. Atmospheric deposition also is a major source of toxic substances accounting for 44% of the bay's total cadmium loading and about 17% of the copper and lead loadings. PAHs also enter the bay from the atmosphere.

10. Industrial and domestic point sources also contribute about 30% of the bay's total loadings of aresenic, cadmium, chromium, and copper.

Puzzle Piece 5: *The Watershed* Management *Plan:* The state's Surface Water Improvement and Management (SWIM) program was established by the legislature in 1987. Tampa Bay was named in the SWIM Act as a priority waterbody within the Southwest Florida Water Management District and a SWIM Plan was adopted in 1992. In 1990, Tampa Bay was adopted into the National Estuary Program by EPA leading to the development of *Charting the Course,* a Comprehensive Conservation and Management Plan (CCMP) for the bay. Community participation was an essential component of the development of both watershed plans. In particular, many of the agencies, citizen groups, and others long active in the restoration and management of Tampa Bay participated in the development of the CCMP. The CCMP built on many of the region's ongoing environmental programs, from land acquisition to urban stormwater retrofitting to habitat restoration. It also identified where unneccesary duplication existed in current environmental programs and provided recommendations to ensure that limited public funds are spent in the most environmentally effective manner.

Puzzle Piece *6: Setting Priorities:* To assure that limited financial resources were used judiciously, restoration projects and programs were prioritized and targeted to specific subbasins. This was done by combining GIS analysis with watershed modeling and characterization with the results of the sediment, biological, habitat, and chemical assessments. For example, an essential early activity of the SWIM program was a watershed-wide assessment of pollution sources, especially stormwater, to identify "hot spots" - subbasins with high stormwater loadings - and to prioritize urban stormwater retrofitting projects (SWFWMD, 1990). Similarly, priority habitat restoration sites were also selected as were projects to reduce overall nitrogen loadings to the bay, including those from atmospheric deposition.

fuzz/e *Piece* 7: *Action Hans:* A successful watershed management plan must include a specific set of actions that will be taken within a specified time. *Charting the* Courseincludes 41 specific actions that are needed to achieve the plan's goals. These include the construction of numerous urban stormwater treatment and habitat restoration projects that have been built, are underway, or are planned in priority subbasins (Figure 4). Since vacant land in the highly urbanized area is scarce or extremely expensive, many of these projects are being conducted on existing public lands providing multiple benefits including regional stormwater management, open space, and recreation. Public education is a frequent component of these projects with the placement of signs depicting the effects of urbanization, the importance of wetlands and riparian vegetation, and the need for stormwater treatment and habitat restoration.

Programs and actions that rely upon nonstructural BMPs are also being used to reduce "Pointless Personal Pollution" at its source and increase the effectiveness of existing programs. For example, since surveys showed that up to 70% of the stormwater BMPs serving new development are not being properly maintained, assuring their long-term operation and maintenance can greatly reduce stormwater pollution. Maintenance and operation of BMPs typically is the legal responsibility of private land owners and property owner associations. Unfortunately, DEP, SWFWMD, and local governments do not have enough staff to conduct regular inspections. To improve this deficiency, DEP is implementing, in cooperation with local governments and the WMDs, a training and certification program for public and private sector individuals involved in erosion, sediment, and stormwater inspections. Local governments also are encouraged to implement Stormwater Operating Permit systems which require an annual inspection and certification that the stormwater system has been maintained and is properly operating. As an economic incentive, some local stormwater utilities provide credits for individuals served by a properly maintained and operating system. Additionally, Hillsborough County has implemented the "Adopt a Pond" program to help educate stormwater system owners on how to maintain their systems.

Other nonstructural efforts include assisting businesses in developing and implementing pollution prevention plans and the continued implementation of the Florida Yards and Neighborhoods Program. This program is being expanded to help develop model landscaping guidelines for commercial landscapes, and promote the incorporation of FYN

Figure 4. Active SWIM Habitat Restoration and Stormwater Retrofitting Projects

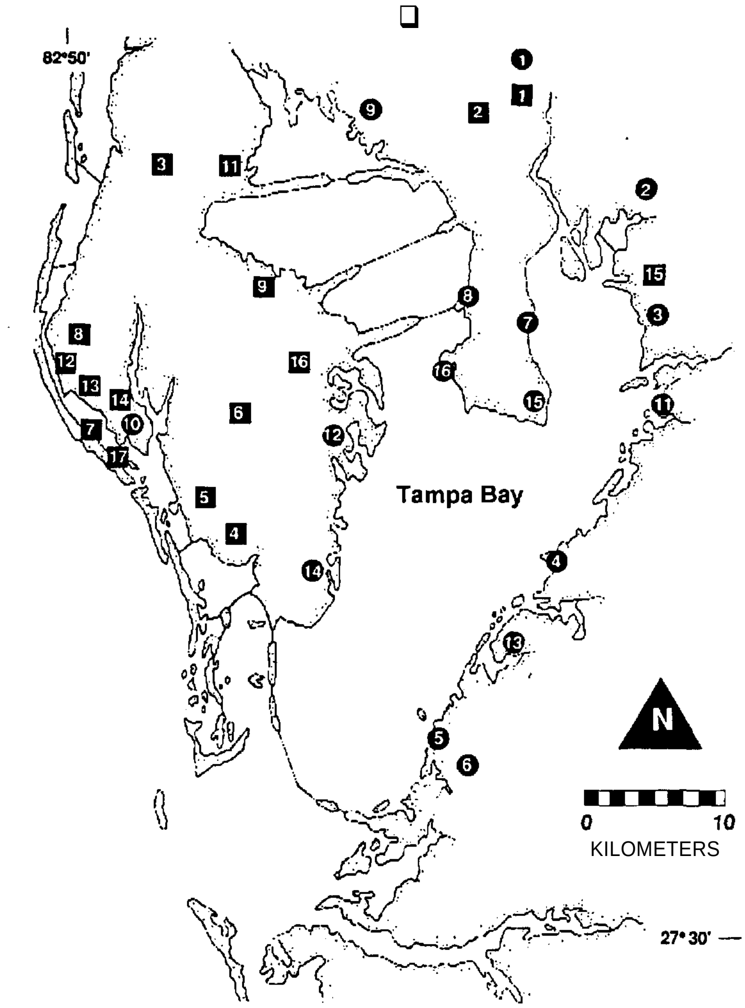

Figure 4. Active SWIM Habitat Restoration and Stormwater Retrofitting Projects.

landscaping guidelines into local government site review processes for new development. The region's continuing rapid growth provides opportunities through local government comprehensive plans and land development regulations to promote compact development and to reduce impervious surfaces, especially parking lots at commercial developments.

Puzzle Piece 8: *Assuring* Implementation: An important aspect of any watershed management program is an institutional framework that assures that all of the partners will implement their responsibilities. In 1998, an Interlocal Agreement was signed by the Tampa Bay NEP's local government and regulatory implementation partners. The agreement requires the partners to submit detailed plans describing how they will fulfill their responsibitlities for bay restoration and protection. Additionally, all of the local governments within the watershed have been issued, either as individual permittees or co-permittees, NDPES muncipal stormwater permits. These permits include specific requirements that are identified in the CCMP's action plans.

Active Habitat Restoration Projects ●

1. Lowry Park
2. NE McKay Bay
3. Delaney Creek
4. Simmons Park
5. Hendry Fill
6. Peanut Lake
7. Bayshore Blvd.
8. Gandy Park
9. Cabbage Head Bayou
10. Boca Ciega
11. Cargil S. parcel
12. Mangrove Bay
13. Cockroach Bay
14. Little Bayou
15. MacDill AFB
16. Picnic Island

Active Stormwater Retrofitting Projects ■

1. Lowry Park
2. Horizon Park
3. Old Coachman
4. S. Pasadena
5. Jungle Lake
6. Pinellas Park
7. N. Redington
8. EMS Site
9. St. Pete/Clearwater Airport
10. Brushy Creek
11. Safety Harbor
12. 102nd Avenue
13. 94th Avenue
14. Lake Carroll
15. Delaney Creek
16. Haynsworth
17. 141st Avenue

Puzzle Piece 9: Funding *Implementation:* Partners in the implementation of the CCMP include EPA, Florida DEP, SWFWMD, local cities and counties, and the private sector. Each of the partners has made a substantial commitment of financial resources since 1995 to accomplish the desired aquatic ecological goals. Primary funding sources have included the P2000 (state and local land acquisition funds), the SWIM Program (state and SWFWMD funds), SWFWMD Basin Boards, the private sector, and local stormwater utility fees. In many cases, funding for projects is from a combination of sources that often allow the leveraging of other funds needing nonfederal matching funds such as those from the Section 319 nonpoint source implementation grant program.

Costs associated with the individual actions presented in the Tampa Bay SWIM Plan and the NEP CCMP are considerable. However, these should not automatically be construed as requirements for new sources of revenues, since some of these initiatives can and are being accomplished with existing resources or by redirecting current funding allocations to better address the bay's needs. A number of actions seek to improve coordination, cooperation, and planning among state and local governments, and the private sector. These may actually result in cost savings for currently funded activities.

A 1994 survey by the Tampa Bay NEP attempted to quantify how much money is spent to manage and monitor bay quality and administer environmental programs. Based on FY94-95 budgets, the study indicates that over $260 million is spent annually by federal, state, and local agencies on the restoration and management of Tampa Bay. As seen in Figure 5, the largest par-t of the funds (65% or $170 million) are spent on wastewater collection, treatment, and reuse.

Figure 5. Funds Spent

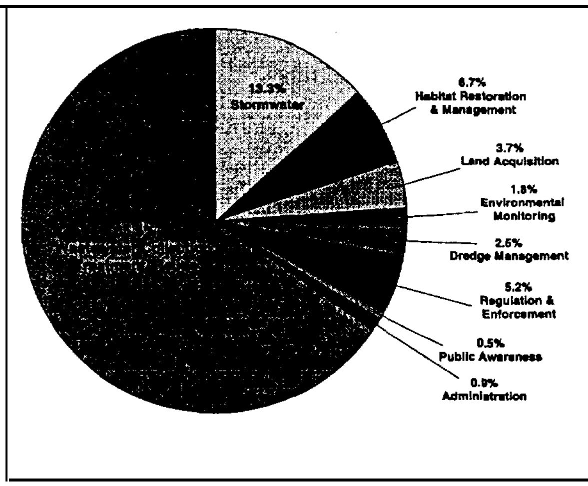

Figure 5. Funds Spent.

Approximately $35 million (13%) is spent by local governments and the SWFWMD on stormwater management. Habitat restoration and land acquisition, two long favored and implemented environmental programs in the Tampa Bay region, account for over $27 million in expenditures.

Puzzle Piece 10: Monitoring Implementation: Since the adoption of *Charting the Course* in 1996, numerous projects and programs have been implemented. The Tampa Bay NEP recently issued the first official progress report on implementation (TBNEP, 1999). It shows that the program's partners are on or ahead of schedule in achieving most of the priority goals for bay improvement. Highlights of implementation activities that occurred between 1995-99 include:

- Goal: Recover an additional 12,350 acres of seagrassover 1992 levels, while preserving the bay's existing 25,600 acres.

  Status: Since 1988, seagrass acreage is increasing at about 500 acres per year meaning the goal will be reached in 25 years.

- Goal: Restoring and protecting bay habitats

  Status: A total of 250 acres of low-salinity habitat will be restored in all bay segments, exceeding the five year target by 150 acres. Additionally, a total of 1,340 acres of mangrove and saltmarsh habitat have been restored. All 28 priority sites identified in the habitat master plan have been given the highest priority for acquisition under the state's land-buying programs.

- Goal: "Hold the line" at nitrogen loadings estimated from 1992-94.

  Status: When fully implemented, the 105 projects constructed, underway, or planned will reduce the amount of nitrogen entering the bay by an average of 134 tons per year, exceeding the target by 60%.

In addition to progress on the above goals, very good progress has been made on other goals. These include:

- The goal of protecting the endangered manatee population in Tampa Bay. The Manatee Awareness Coalition has implemented "Manatee Watch" where trained volunteers help educate and encourage boaters to go slow in waters frequented by manatees.
- The goal of returning bay scallop to Tampa Bay. Stocking programs are adding bay scallops and citizen volunteers are measuring the effectiveness of these efforts through the Great Bay Scallop Search.
- The goal of reducing atmospheric deposition into and onto Tampa Bay. To better understand the linkage between air pollution and water quality, eight research and monitoring programs addressing atmospheric deposition are underway.
- The goal of making Tampa Bay safe for shellfish harvesting and swimming. As part of the "Healthy Beaches Project", research is underway to identify and test better indicators of microbial contamination, the prevalence of the indicators at bay and gulf beaches, and probable sources of the contamination.
- The goal of providing flows necessary to support plant and animal communities below the dam on the Hillsborough River. In February 1999, the SWFWMD approved a draft minimum flow rule for the Hillsborough River that hopefully will provide a basis for resolving conflicts over competing uses of the river.
- The goal of developing a long term dredge material management plan for Tampa Bay. A Dredged Material Advisory Committee is being organized in partnership with the U. S. Army Corps of Engineers.

Discussion and Recommendations

Florida has established a wide variety of laws, regulations and programs at the state, regional and local level to protect, manage and restore the state's incredibly valuable yet vulnerable natural resources, especially its water resources. There is no doubt that these programs have been effective in helping to reduce adverse impacts on natural resources resulting from the state's rapid and continuing growth over the past twenty years. However, even with the implementation of these programs, many of Florida's natural resources have been severely strained or degraded. Some of these adverse effects can be attributed to activities that occurred before the implementation of modern watershed management programs such as the channelization of the Kissimmee River and the creation of the vast drainage canal network south of Lake Okeechobee both of which are contributing to the decline of Lake Okeechobee, the Everglades and Florida Bay. Other adverse impacts, though, are directly related to the state's rapid growth and development during the last twenty years. These include water supply problems, water quality problems, declining habitat and impacts on endangered species such as the manatee and the Florida panther.

Why are these adverse impacts still occurring given the wide range of watershed management programs that have been implemented in Florida? What could be done to reduce these effects and possibly restore already degraded areas? The continuing evolution of Florida's land and water management programs into a more holistic approach which seek to manage cumulative effects can help to overcome many of the current program deficiencies. Cooperative efforts and partnerships, together with citizen education and involvement to improve the stewardship ethic of all Floridians is essential. With increased support and participation by all Floridians, the effectiveness of the state's programs can be improved helping to assure that our natural resources will be able to be enjoyed by future generations.

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Urban Stream Structure And Selection Of Structures To Build Habitat To Support Wild Fish Populations

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Abstract

This paper gives a brief overview of the physical impacts of urbanization on streams and examines the selection of in-stream methods, tools, and devices for stabilizing streams and creating habitat to support native fish species. Although the paper discusses salmonid species in the Pacific Northwest in particular, the methodologies and tools employed to evaluate and support fish habitat can be generally applied to streams and watersheds in other regions.

The effects of urbanization, such as decreased pervious area and vegetative cover and increased stormwater runoff and erosion, destabilize watersheds and streambeds and destroy aquatic habitats. Stable stream environments are necessary if biological systems including fish and their supporting food web are to flourish. Changes to urban streams and watersheds may be so significant, however, that decades may pass before they reach stability. Even then, the resulting Astable environment@ might not provide the type of habitat needed to support species from the natural environments.

The evaluation of channel erosion and sedimentation in urban streams provides one measure to assess the relative stability of streams and, thus, their ability to support fish and amphibian species. For most streams, an evaluation of relative streambed stability can be completed through a visual examination of streambed morphology and minimal supporting calculations. Tools for performing these analyses will be presented in this paper.

Rehabilitation of streams in urban and heavily logged watersheds requires establishing a stream structure that will maintain streambed stability and create the different types of habitats needed to support desired fish species. One size or type of in-stream device cannot meet all stabilization and habitat requirements. The selection of devices should correspond to the relative stability of the individual stream reach. Devices for maintaining streambed stability and creating habitat, as well as the procedures for selecting them, will be discussed in this paper.

Introduction

Salmon populations in the Pacific Northwest are dwindling. One significant cause of this reduction in population is the destruction of small stream (1st to 4th order) habitats.

In order to respond to the destruction of fish habitat in small streams, we must have an understanding of watershed processes and natural stream morphology. Although this paper concerns western Washington streams, which are surrounded by heavy forests and fed by rain and groundwater, the general principles for stabilizing streams discussed here can be applied to most natural small stream systems.

Natural Stream Morphology

Streambed gradients gradually decrease from the upper reaches of a watershed to the outlet of a stream because flow rates increase in the lower parts of the watershed (Leopold, Wolman, and Miller, 1964).

The streambed gradients create different types of fish habitat features (Rosgen, 1994). Figure 1 shows the relationship of habitat type to streambed slope in western Washington streams. Pool/drop habitat is dominant in reaches with smaller flows and steeper valley gradients. The pools are formed by large organic debris or rock formations. As the stream flow rates increase, valley gradients tend to decrease and the streams are dominated by pool/riffle habitats.

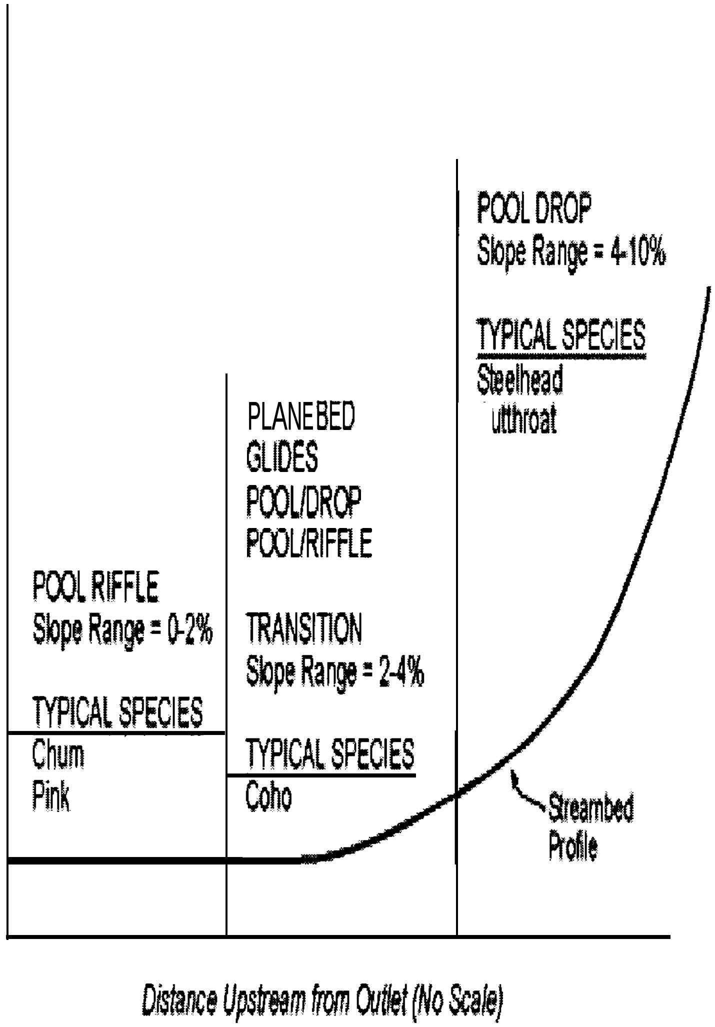

Figure **1.** Relationship of Stream Habitat to Streambed Slope in Western Washington Streams.

Pools and riffles form alternately on the outside of stream bends. These alternating pools and riffles are present in practically all perennial channels. In straight or meandering streams, pools and riffles generally form every 5 to 7 channel widths. As the stream widths increase, however, the number of pools decrease (Leopold, Wolman, Miller, 1964).

In each non-rigid, natural stream, a dominant channel is formed by the **stream=s** dominant discharge. This dominant discharge channel is a component of most fish habitats. The dominant discharge has a recurrence period of approximately once each 1.5 years in natural systems (Simons, Senturk, 1991). In urban systems, the bank-full discharge has a recurrence period of about one year **(MacCrae,** 1996).

Western Washington Natural Stream Characteristics The small streams of western Washington are fed by rain and groundwater and are found in steep-sided canyons with fairly straight valley bottoms. In their natural (forested) state, small streams have a slightly meandering, low-flow channel in a narrow valley bottom. The vegetation along the stream banks is often dense and provides shade, channel stability, and cover. Debris jams are common and act to slow stream flows during storm events. Western Washington soils are products of glacial activity and consist of smooth cobbles and stones, as well as fine materials. Clayey bank materials, heavy root structures along the banks, and steady base flows create channels with nearly vertical sides and small widths (3 to 6 feet wide, and sometimes as small as 1 foot wide) relative to the width of the valley bottom. Typical old-growth forest streams have low nutrient levels and low annual sediment yields.

Most natural Pacific Northwest streams can be described as sediment starved. Natural watersheds are heavily forested and act as a sponge for rainfall. In natural watersheds, the storm runoff response is slow and the flow rates are low. Because the ratio of the 1.5-year storm to the base flow is quite low (often less than 5), these streams have small width to depth ratios, with most of the dominant discharge channel acting as an aquatic habitat channel. The width of the dominant discharge channel is coincident with the width of the aquatic habitat channel. The aquatic habitat channel is the normally wetted, low-flow part of the streambed (Seattle, 1997). Most small, natural Western Washington streams are dominated by pools and drops formed by large organic debris (Gustav, Sovern, Washington, 1993)

The aquatic biological community in western Washington may include as many as 250 plant and animal species. The aquatic biological community depends on a stable aquatic habitat associated with old growth, coniferous watersheds. Much of this aquatic community functions as a food web, with fish populations representing the mega fauna. Some salmon and trout species are the top aquatic predators (Sovern, Washington, 1996).

Salmon and trout in western Washington evolved to take advantage of these regional stream conditions. Figure 1 lists different species found in the various regions of the watershed. More athletic fish species like coho, steelhead, and cutthroat trout occupy the upper reaches (steeper gradient) of the watershed. The young coho and steelhead reside in the stream for a year before migrating to saltwater. Cutthroat may reside in fresh water for two years before migrating to saltwater. Less athletic species, such as chum and pink salmon, can not migrate through the steeper gradients of the upper watershed to spawn. The fry of these species occur in the lower regions of the watershed and migrate to saltwater shortly after emergence. Young salmon, as well as young and adult trout, will utilize any part of the watershed that meets their habitat requirements. For example, if fish habitat in the upper reaches of a watershed is unsuitable, young coho may seek winter refuge in the lower regions of a watershed (Sovern, Washington, 1996).

Five general categories of habitat occur in natural western Washington streams (Sovern, Washington, 1996):

- Estuaries/Deltas
- Passage
- Refuge
- Rearing
- Spawning and Incubation

Pacific Northwest fish derive most of their food from organisms (benthos) that live in, or on, the substrate of the stream. Most food production occurs in the same stream areas that provide spawning and incubation habitat for fish. An annual surplus of approximately 10 pounds of biomass is required to support one pound of fish in the stream (Washington, 1999).

Assessing Stream Deterioration

Visual inspection of stream morphology can provide rapid and relatively accurate assessments of a stream=s ability to support fish populations. Practical experience working in western Washington streams has shown that visual streambed assessments correlate well with benthic sampling (Seattle, 1999). Although benthic sampling is necessary, visual inspections can reduce the amount of benthicsampling required when quickassessments are needed orextensive benthic testing is cost-prohibitive.

Natural streams are generally non-rigid. Their cross-sections vary with changes in flow rates and yearly rainfall volumes. Stream systems will generally aggrade during low flow periods, and degrade during high flow periods. To assess the deterioration of non-rigid streams, it is necessary to understand the following three concepts:

*Sediment transport

*Effects of urbanization on stream stability

*Effects of urbanization on fish habitat

Sediment Transport Concepts Understanding the dynamics of sediment transport is useful for predicting hydraulic equilibrium conditions in a stream. Any stream will respond to imposed changes. Six basic relationships exist between discharge levels and channel form, regardless of stream size (Simons and Sentürk, 1991):

Depth of flow in the dominant discharge channel is directly proportional to discharge.

- Width of the dominant discharge channel is directly proportional to water discharge and sediment discharge.
- Dominant discharge channel shape is directly related to sediment discharge.
- Channel gradient is inversely proportional to water discharge and directly proportional to sediment discharge and grain size.
- Sinuosity is directly proportional to valley gradient and inversely proportional to sediment discharge (larger valley gradient causes greater meander, larger sediment discharge causes less meander).
- Transport of bed materials is directly related to flow velocity and concentration of fine material, and inversely proportional to the fall diameter of the bed material (greater depths and higher velocities cause larger bed load volume in transport, sediments shaped like kites fall slower than round-shaped sediments).

A stable channel exists when a stream has the bed slope and cross-section which allow its channel to transport water and sediment from upstream without aggradation, deposition, or streambank erosion (Simons and Senturk, 1991).

When natural flow rates are exceeded, sedimentation and erosion can be a dominant limiting factor for fish populations. The exaggerated volumes and rates of stormwater runoff in urban areas increase both the rate of erosion and volume of sediments generated from upland and riparian areas in the watershed. Soil erosion can lead to excess streambed erosion and sedimentation and destroy redds, fish rearing habitats, and food production areas.

Effects of Urbanization on Stream Stability Urbanization permanently alters the hydrologic balance within stream in the following ways:

- Total water passing through urban streams increases.
- Stormwater runoff rates and volumes increase.
- Increased impervious surface areas prevent groundwater recharge; as a result, base flow rates during summer and fall are often less than natural flow rates were.
- Increased stormwater runoff causes erosion and transports significant amounts of sediments and pollutants, including oil, grease, and polluted fine sediments from streets and parking lots, into urban streams,

In urban areas, the ratio of the 1 -year storm to the stream=s base flow (dominant discharge) is large, sometimes greater than 100. In many watersheds, terrestrial sediment volumes are dramatically increased by urbanization. Excess sediment increases the width of the dominant discharge channel.

Stable urban streambeds have 182% gradients, compared to the 2810% gradients that support anadromous species in natural watersheds. To reach a stable gradient, the streambed can lower several feet, causing significant bed load sediments from shallow landslides. Measurements taken from several western Washington streams show that streambeds will flatten from a 4% gradient to a 1% gradient as a result of urbanization. A change in streambed gradient from 4% to 1% over the distance of 1,000 feet can result in streambed erosion and an elevation difference of 30 feet at the upper end of the reach. During the transition from steep to flat gradients, fish habitat is in a perpetual state of change (Sovern, Washington, 1996). Unfortunately, it can take decades before stability is again reached.

In unstable streams, braiding occurs at crossover points between bends where stream gradients are steep. At normal stage, a braided section has a divided flow with small, mid-channel bars and a single large channel composed of subordinate channels. The base flow channel often changes location within the bottom of the dominant discharge channel (Sovern, Washington, 1996).

The erosion of the channel bottom along the basin (often called head-cutting) indicates a readjustment of the basin's gradient, the stream discharge, and the sediment load. (Simons and Sentürk, 1991).

Effects of Urbanization on Habitat Stable habitat conditions within the channel have stringent requirements in urban streams, including a sediment-starved condition and minimal movement of spawning-sized gravel (3-inch and smaller) during most storm runoff events.

In urban streams, the benthic system can be limited both by erosion (which provides conditions of constant change) and by sedimentation (which smothers redds and food production areas, and fills rearing habitats with silt). In addition, streams in urban or deforested watersheds experience significant habitat loss and are unable to support the biological diversity that fish species depend upon. In contrast to natural watersheds, where 250 plant and animal species may comprise the aquatic habitat, urban watersheds may have fewer than 50 plant and animal species.

Living systems do not adapt to constantly changing environmental conditions. The changes in aquatic habitats caused by urbanization decrease food production and destroy spawning and incubation areas (Bell, 1990). As flow rates and volumes increase, streambeds become unstable. When streambeds become unstable, the aquatic habitat channel may retain a small width to depth ratio, but it will be substantially less than the width of the dominant discharge channel. In addition, streambed instability causes a constant shifting of the aquatic habitat channel and this limits development of the benthic community and destroys redds.

As an urban stream approaches stability, the resulting aquatic habitat channel will be too wide, shallow, and homogeneous to support fish populations. Streams naturally deposit bed load on the inside of bends and form point bars. Because natural sinuosity is low in western Washington streams, point bars form infrequently or incompletely leaving a wide, shallow, cross section during base flows. Under these conditions, the flow depths of most urban streams are insufficient to submerge returning adult fish. Because small-grained sediments settle as flow rates decrease, redds and food production areas are smothered with silt and pool habitats are filled with sediment.

Perhaps the greatest general impact is the permanent loss of habitat types that sustain coho and steelhead populations. These species prefer pool/drop habitat. Coho, in particular, require quiet pools (Seattle, 1997). Examination of Figure 1 shows that as the streambed gradient lessons, the habitat type shifts from pool/drop to pool/riffle. Pool/riffle habitat does not provide sufficient pool depth for normal fish rearing or urban storm refuge. Because large storms frequently occur after the fry emerge from the streambed gravels, the need for urban storm refuge habitat is critical. Juvenile fish cannot maintain their position in high velocity reaches. In fact, normal urban storm flows often wash juvenile fish into larger bodies of water (salt water or streams) where they cannot survive.

Tools and Methodologies

The methodologies available to assess existing stream conditions and predict future conditions include the use of visual streambed assessments and analytical tools such as simple hydraulic mathematics.

Streambed Assessment

General indicators of habitat degradation in urban streams are visually apparent and include the following elements:

- Dominant discharge channel wider than in natural conditions
- Reduced pool frequency and less diverse habitat
- Increased sediment from terrestrial sources

- Reduced large woody debris
- Drastically reduced aquatic community diversity

Both natural and urban streams fluctuate between stability, degrading, or aggrading. Compared to natural streams, however, streams in urban watersheds exhibit extreme traits of aggradation, degradation, or instability. Urban stream deterioration indicators differ according to the condition of the specific reach (stable, degrading, or aggrading). In a degrading streambed, there is a progressive lowering of the channel due to scour. In an aggrading streambed, there is a progressive buildup or raising of the channel due to sediment deposition. Both degradation and aggradation are indicators that a change in the stream=s discharge and sediment load is taking place (Simons and Senturk, 1991).

Urban stream deterioration indicators differ according to the condition of the specific reach. Table 1 (the following bulleted paragraphs) describes the deterioration indicators in a stable, degrading, or aggrading stream.

Table 1. Urban Stream Deterioration Assessment Indicators

Stable B If an urban stream reach is stable and terrestrial sediment loads are low, the reach may be able to support species that reside temporarily in the stream before moving to salt water. The wide, shallow channel of a stable stream provides little protection from predation, however, and also lacks resting pools. The following are indicators of stable urban streams:

- Apparent changes in channel shape and configuration afler large storms are small.
- Width of aquatic habitat channel coincident with width of dominant discharge channel B shallow flow depth, prevents fish passage.
- Head-cutting and nick points are absent or nearly absent.
- Substrate stability:
  - Periphyton stays on streambed after significant storms B streambed is stable.
  - Streambed gravel lack periphyton B gravel is being moved during significant runoff and replaced when the storm flow recedes,
  - Small-grained sediments settle when storm flows recede, smothering redds and food production areas.
  - Pools (on-stream or off-stream) that can retain newly hatched fry are generally not present.

Degrading B In a degrading urban stream the dominant discharge channel is as wide as in a stable stream, but base flow rarely covers the bottom of the channel except at crossover points between bends. When streams begin to unravel due to degradation, the effects do not appear instantly. Head-cuts move through a stream until it reaches a vertical drop. When enough head-cuts accumulate, the vertical drop will be undercut, releasing large amounts of bed load type sediments. Occasional pools will develop that may support anadromous fish, however, they are often inaccessible.

- Streambed gravel sizes are larger than stable sections of the stream, but are mostly bare of periphyton or other aquatic growth.
- Channel braiding occurs at crossovers between bends.
- The substrate of the base flow channel is not coated with periphyton.
- The base flow channel and dominant discharge channel lack large woody debris.
- Large woody debris that spans the banks of the dominant discharge channel may indicate a recent streambed elevation and may illustrate the amount of degradation that has occurred.
- Stream banks are bare and often nearly vertical.

Aggrading B Aggrading stream reaches may be visually similar to stable reaches. Generally, aggrading streams will have a flatter streambed gradient and accumulate more fine sediment. Disturbing the bed of an aggrading reach usually results in long periods of murky water flow. Aggradation will occur locally in pools, which reduces habitat value, but has less impact on habitat than an entire aggrading stream reach would.

- Head-cuts and nick points do not exist.
- Deltas may be visible at the top of the reach.
- Periphyton covers the substrate.
- Large woody debris in streambed is partially buried.
- Pool/riffle and pool/drop habitat can occur as isolated conditions.
- Substrate surface gravel sizes are small.

The visual indicators described in Table 1 (combined with assessments of fish passage problems and periodic benthic population checks) can be used to describe the potential habitat capacity for a stream reach or, collectively, for an entire stream. Needless to say, habitats for fish species that reside in the stream for one year or longer must be able to support the full life cycle of the species. In addition, fish need to have full access to these habitats.

A methodology based on visual streambed assessment was developed for rapid stream assessments in Longfellow Creek and Pipers Creek in Seattle, Washington (it was also used within six watersheds in Snohomish County, Washington). The streambed assessments provided an accurate measurement of the ability of the watershed or stream in question to support fish. An example of the summary rating for Longfellow Creek is shown in Table 2.

Table 2. Summary Rating for Longfellow Creek

Creek Segment	Description	Map Sheet	Habitat'	Bank Erosion'	Sediments Sources*	Other Pollutants*	Total
1	Pipe from outfall to Andover Street	1,2,3	5	3	3	2	13
2	Open channel from Andover Street to Genessee Street	4,5	10	1	1	2	14
3	Open channel from Genessee Street to confluence of unnamed tributary in West Seattle Golf Course	5,6,7	10	2	2	2	16
4	Unnamed tributary in West Seattle Golf Course	6,7	6	2	2	2	12
5	Open channel from confluence with West Seattle Golf Course tributary to Brandon Street	7,8,9	9	1	1	2	13
6	Open channel from Brandon Street to Findlay Street. Contains confluence of Juneau Street bypass via "biochannel."	9	9	2	2	2	15
7	Open channel from Findlay Street to Juneau Street. Also contains piped high flow bypass starting at Juneau Street and rejoining Creek in Segment 6.	9,10	8	2	2	2	14
8	Open channel from Juneau Street to Graham Street	10,11	11	2	3	2	18
9	Open channel from Graham Street to Willow Street	11,12	8	2	1	2	13
10	Open channel from Willow Street to Myrtle Street	12,13	8	2	2	2	14
11	Piped channel Webster Basin; open channel to Holden Street. Contains "K-Mart bypass."	13,14	7	2	2	2	13
12	Open channel from Holden Street to Thistle Street	14,15,16	8	2	1	2	13
13	Pipe from Thistle Street to head of basin at Roxbury Street	16	6	3	1	2	12

Notes:

Ranking Codes:

1 = Poor condition
2 = Moderate
3 = Relatively good
* = The value in the "habitat" column is the result of another ranking process. The total "habitat" volume for each Creek segment is transferred into this table to complete the ranking process. The habitat rank has a range of O-18 which is developed from evaluating bed erosion, fine sediment accumulation, gravels (clean/stable), benthic (quantity, quality), habitat structure, and riparian vegetation. All other columns in this table are ranked from 1 (poor condition) to 3 (relatively good condition).

Analytical Tools Simple hydraulic mathematical tools can be applied to analyze existing conditions and are needed to check passage conditions for channel rehabilitation projects. In addition to depth and velocity, the amount of turbulence in a stream has significant impact on the amount of sediment that can be moved. Greater turbulence increases the amount and size of sediments that can be moved. Maximum turbulence occurs when the Froude number is equal to 1 .O. The Froude number is defined by Equation 1:

$$F_N = V/(gY)^{1/2} \qquad \text{(Equation 1)}$$

Where

F_N = Froude number

V = average velocity in the cross-section

g = acceleration force due to gravity

Y = the hydraulic depth, which is the cross-sectional area divided by the top width

The Froude number should not exceed 0.8 for large storms (like the 25 or 100-year event) except at channel drops. This criterion is the same for rigid, grass, and dirt lined channels in most stormwater manuals. For frequently occurring storm flows (1 to 2 year events), the Froude number has to be much less in order to meet the criteria for larger flows. Spawning-size gravel will generally be stable if this Froude number criterion is met.

In the author's experience, backwater analysis (HEC-2 or HEC-RAS) may not be strictly applicable to analyze natural streams, but is a useful tool to analyze deteriorated channels and to model proposed improvements for stream rehabilitation. For stream rehabilitation backwater analysis is done for large and small events (base flow, 1 -year flow, and one point in between) to ensure passage of juveniles throughout their life-cycle habitat within the stream. To provide accurate results, more cross-sections are needed to conduct backwater analysis on non-rigid, urban streams compared to conventional backwater analysis.

Selecting Rehabilitation Devices

Unless excess stormwater from both frequent and rare storm runoff events can be eliminated, it is the author=s opinion that some form of structural intervention is needed to create fish habitat in urban streams. In western Washington, streams become unstable and significant fish habitat is lost when the impervious area reaches 10 to 15 percent (Booth, 1996). The dominant discharge channel will respond to hydrologicchanges (Simons and Senturk, 1991). As a result, modifying how land is urbanized can reduce the effects of urbanization, but it will not obviate the hydraulic impact on the dominant discharge channel. Stream rehabilitation measures will still work best where there are fewer disturbances to the watershed and where wide riparian corridors are maintained.

The goal of urban stream rehabilitation is to stabilize the streambed with devices that also create a habitat for fish populations. The stream must develop sufficient food mass and diversity to support desired fish species. Quality salmon and trout habitat can exist in urban streams when hydraulic/habitat criteria are met, the streambed is stable, and the base flow channel is confined (Sovern and Washington, 1996).

Establishing stable streams in urban watersheds is often a moving target. As more urbanization occurs, hydrologic and biological changes accumulate. The extent that the dominant discharge channel spreads is a direct function of the amount of pavement in a watershed.

The New Urban Stream. Restoring an urban stream to pre-development conditions is not possible (National Research Council, 1992). It is the author's opinion that too many stream rehabilitation projects emphasize stream bank rehabilitation rather than focusing on the root causes of stream habitat destruction. Often, that root cause is streambed instability, which is a natural response to increased flow rates and volumes in the stream.

To maintain pre-development species in urban and deforested streams, a "new urban stream" is needed that can provide a variety of fish habitats including pools. Without intervention, the urban streams will convert pool/drop habitat into pool/riffle habitat, eliminating the diversity of habitat required to support a variety of fish species (Sovern and Washington, 1996).

The goal is to stabilize the stream and return it to its original sediment-starved condition. While bed load and suspended sediment are readily available, the object is to sculpt sediment deposition to form bars and banks and confine the aquatic habitat channel within a single location. Concentrating flows in the aquatic habitat channel helps keep the substrate size optimal and clears the stream of fines.

Urban stream rehabilitation must focus on historic conditions that can be recreated, rather than on the conditions that cannot be meaningfully restored. Except for the following three exceptions, historic environmental conditions can be recreated in urban streams:

- The width of the dominant discharge channel will always be greater in urban streams.
- The banks of the aquatic habitat channel cannot be coincident with the dominant discharge channel (in pool/riffle habitat).
- High flood flows, deep flow depths, and large velocities are more frequent.

In form, the resulting channels resemble snowmelt type streams, where flow rates significantly exceed base flows for several weeks each year. Most urban streams lack large woody debris that can be incorporated into the stream's structure when a reach attains stability. Most reaches will take decades to reach stability. Just because the channel will not look "natural", doesn't mean that we will have failed or that anadromous species cannot be supported. Many eastern Washington snowmelt type streams support anadromous species.

A rehabilitated stream has five primary needs:

- A dominant discharge channel sized to carry the 1 -year to 1 S-year storm (depending on the degree of urbanization) at full bank. It is important to recognize this need because the stream will reshape the dominant discharge channel and may undo much of the rehabilitation effort.
- Within the dominant discharge channel, hydraulic conditions must provide biologic and stream stability (keep most of the spawning sized gravel and rock from moving during frequent storms).
- Within the dominant discharge channel, habitat must be provided for the entire life cycle of the desired species.
- Because fine-grained sediment falls out last and needs to be kept in transport, the base flow channel has to be narrow, deep, and stable.
- Stream banks need to be stable to support riparian vegetation. Bio-stabilization techniques can help reduce the width of the dominant discharge channel.

Ideally, long reaches of unstable streams will be stabilized. Near the spanning structures, aggradation will replace degradation (as long as a sediment supply is available). If only short reaches are stabilized, large storms will deposit substantial sediments within the stabilized reach, particularly at the upstream end of the reach. The sediment sizes most likely to accumulate during the stabilization of a reach are the larger sizes that are moved as bed load. Once stable streambed gradients are attained, the amount of sediment that can move and cause aggradation is finite. After a few larger storms, bed load movement will be minimal.

Rehabilitation Devices A variety of devices may be used to confine the base flow channel and provide streambed stability. The author has experience with several types of bed control structures, glides, lunkers, and confining devices. In small streams, these devices may be a well-placed piece of timber, a boulder, or randomly placed stones and rootwads (to increase roughness). In larger streams, stabilization and confining devices are much more complex.

Selection and siting of devices is dependent on the stream condition in a specific area and the type of habitat that is to be provided. It is important to realize that one type of structure is not suitable for all applications. Selection of a stream rehabilitation device depends on the type of habitat needed and the device's perceived hydraulic attributes. Both non-rigid channel design and biologic skills are required to be successful.

This section will address issues related to the selection of three types of structures: timber stepdown structures, boulder bed control structures, and deflectors.

Timber *Stepdown stepdown*. Sometimes referred to as a "K-structure". A form of timber is shown in Figure 2. The logs, which are set at 45 degrees to the channel, are called weir logs and create pools during high storm flows. The weir logs need to have a steep pitch (the bank end higher than the center of the stream). In dense, urban western Washington watersheds, storms with high yearly return frequencies produce flows 20 to 50 times the base flow. Timber stepdown structures form large, quiet pools during storms, allowing newly emerged fish juveniles to find refuge. In

Figure 2. Timber Stepdown K-Structure (shown with weir logs).

addition, the K-type stepdown creates rollers. Rollers assist fish passage upstream for less athletic adults and juveniles during higher flow rates (Kerr Wood Leidal Associates, LTD, 1980).

Common variations of the K-structure include a straight timber stepdown (no weir logs) and a vortex structure (with weir logs). In creating a diverse habitat environment, both types can be used.

While the straight timberstepdown does not form an upstream pool, the substrate above the stepdown is turned-over, even for frequently occurring storm flows. The Washington Department of Fisheries and Wildlife has successfully installed many straight timber stepdowns in logged watersheds and those with minimum to moderate urbanization. For lower flow rates, the substrate above the stepdown remains stable and provides excellent spawning habitat.

The vortex type timber stepdown does not form storm refuge pools as well as the k-structure and the log configuration stymies formation of a roller. The structure can help develop confined low flows, however, and creates good fish-rearing habitat for many northwest species (not Coho).

Boulder *Bed* Control Structure. Figure 3 shows a boulder bed control structure. Like the K-structure, the boulders that form the structure are on the upstream side, but these boulders could also be on the downstream side to form a vortex-type structure. In the author's experience, changing the configuration and the angles of the boulders provides slightly different habitat characters, all of which are acceptable. While wood is usually preferred in small streams, boulder bed control structures are flexible and can adjust to channel degradation in unstable streams. Boulder bed control structures are most beneficial at the downstream end of a reach where no streambed control is established in the reach below.

Deflectors. Deflectors can be made of either wood or boulders. Figure 4 shows a timber deflector with a bank log on the opposite bank. Point bars form on the insides of bends. Deflectors should be installed on the insides of bends to help build larger point bars and to confine the base flow channel. The reach in Figure 4 is nearly straight (sinuosity about 1 .O). To develop point bars in straight reaches, several deflectors may be needed and could be on one side of the channel, or on alternating sides. The reach shown in Figure 4 has a large bed load, and point bar formation would have occurred if the deflector installations were correctly located and implemented. Without modification, however, the deflector shown in Figure 4 will not form a point bar.

Figure 3. Boulder Bed Control Structure.

Figure 4. Deflector.

Conclusions

Streambed assessment based on sediment transport principles can be a useful tool to rapidly determine a stream's capability to support fish populations. Standard engineering analytical tools can be used with streambed assessment to support hydraulic design for stream rehabilitation projects. Although the stream will not have the same appearance as a natural stream, stream rehabilitation can be successful and urban streams can support anadromous fish populations in western Washington. Hydraulic design is needed to develop the dominant discharge channel and properly place structures to attain the desired habitat conditions. Selection of the rehabilitation devices must consider design needs of non-rigid channels, as well as habitat requirements. Finally, one size or type of habitat rehabilitation device cannot serve all purposes. Selection of habitat rehabilitation devices should achieve specific habitat requirements and provide habitat diversity.

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Lessons Learned About Successfully Using Infiltration Practices

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Abstract

Infiltration practices are one of the most valuable urban stormwater BMPs because they not only help to reduce stormwater pollutants but, more importantly, help to reduce stormwater volume. Unfortunately, infiltration practices have gotten a bad reputation over the past 20 years because of their potential to fail. This paper will review the successes and failures of the use of infiltration practices in the United States. It will summarize the lessons that have been learned about the use of infiltration practices. This will include recommendations on when they should be used and how, and recommendations on when they should not be used. Finally, the paper will discuss what can be done to reduce stormwater volume when infiltration practices cannot be used successfully.

Introduction

To achieve the desired objectives of flood control, water quality protection, erosion control, improved aesthetics, and recreation, a stormwater management system must be an integral part of the site planning for every development site. Although the basic principles of stormwater management remain the same, each individual site and each specific project presents unique challenges, obstacles, and opportunities. The many variations in climate, soils, geology, groundwater, topography, vegetation, and planned land use require site-specific design.

The natural attributes of each site will strongly influence the type and configuration of the stormwater system. These features will suggest which particular combination of Best Management Practices (BMPs) can be successfully integrated into an effective system. Whenever site conditions allow, the stormwater management system should be designed to achieve maximum on-site storage of runoff by incorporating infiltration practices throughout the remaining natural and landscaped areas of a site. A stormwater management system should be viewed as a "treatment train" in which the individual BMPs are the cars. Generally, the more BMPs that are incorporated into the system, the better the performance of the treatment train. Inclusion of infiltrative practices as one of the cars should be a primary goal of stormwater system designers, even on sites where detention practices will be the primary BMP.

Infiltration practices (or retention practices) retain stormwater on-site, allowing it to soak into the ground or evaporate. There are a number of different infiltration practices that have been widely used throughout the United States, including basins, trenches, dry wells, pervious pavements, and swales. Often infiltration practices include vegetation with a wide variety of trees and shrubs. In 1987, Prince George’s County, Maryland, began evolving this type of infiltration practice into “bioretention,” which is a BMP that uses the soil matrix and vegetation to sequester pollutants within the terrestrial environment (PGC, 1993, 1997)

Infiltration practices are one of the few BMPs that can help to assure that all four stormwater characteristics (volume, rate, timing, and pollutant load) after development closely approximate the conditions which occurred before development. That is because infiltration practices help to maintain pre-development site perviousness and vegetative cover, thereby reducing stormwater volume and discharge rate, which further promotes infiltration and filtering of the runoff.

The benefits of infiltration include reducing stormwater volume and peak runoff rate; recharging groundwater, which helps to replenish wetlands, creeks, rivers, lakes, and estuaries; augmenting base flow in streams, especially during low flow times; settling and filtering of pollutants as they move through the system’s vegetation and surficial soils; lowering the probability of downstream flooding, stream erosion, and sedimentation; and providing water for other beneficial uses.

Another benefit of infiltration practices is their ability to serve multiple uses since they are temporary storage basins. Recreational areas (e.g., ballfields, tennis courts, volleyball courts), greenbelt areas, neighborhood parks, and even parking facilities provide excellent settings for the temporary storage of stormwater. Such areas are not usually in use during periods of precipitation and the ponding of stormwater for short durations does not seriously impede their primary functions.

Longevity of Infiltration Systems

One of the problems with infiltration BMPs that has been consistently identified, either quantitatively or qualitatively, is their high rate of failure. Maryland’s Stormwater Program produced one of the most comprehensive quantitative reviews of the longevity of infiltration systems (Pensyl and Clement, 1987; Lindsey et al, 1992). This information is summarized in Table 1, where it can be seen that the overall condition and functioning of infiltration systems declined over time. In 1986, about two-thirds of all surveyed facilities were functioning as designed, while in 1990, only about half were. Only 42% of the facilities were functioning as designed in both 1986 and 1990, while about 27% were not functioning as designed in both years. About 24% of the systems were functioning in 1986, but not in 1990; while only 7% of those not working in 1986 were working in 1990. Maintenance was needed at more facilities in 1990 (66%) than in 1986 (45%). Additionally, 38% of facilities that needed maintenance in 1986, still needed maintenance in 1990, while 32% of the facilities that did not need maintenance in 1986, did need it in 1990. Only 10% of the systems that needed maintenance in 1986 did not need maintenance in 1990. These data suggest that little effort is expended on maintaining the operational capabilities of stormwater management systems.

Additional quantitative information on the success and failure of infiltration systems was collected in the Puget Sound, Washington, area (Klochak, 1992; Gaus, 1993; Hilding, 1993; Jacobson and Horner, 1993). Of 23 infiltration basins evaluated, 12 did not comply with the region’s guidelines for either infiltration rate or time for the basin to recover its storage volume. Interestingly, the authors found no relationship between lack of basin maintenance and failure, with examples of basins with and without maintenance that did not function properly. Some basins were functioning properly even though they had never been maintained, while 43% of the 23 basins had been scarified to enhance performance.

The above data, when combined with qualitative information from Florida and Delaware (Baldwin, 1999, personal communication), seem to indicate that infiltration basin failures are associated with:

1. Inaccurate estimation of infiltration rates

2. Inaccurate estimation of the seasonal high water table

3. Excessive compaction during the construction process

4. Excessive sediment loadings either from improper erosion and sediment control during the construction process or a lack of pretreatment BMPs

5. Lack of maintenance

Factors Influencing Successful Use of Infiltration Systems

Factors that influence the successful use of any stormwater BMP can be categorized as institutional, technical, and implementational. This section of the paper will examine the components of each of these categories that must be included in a stormwater program if the causes of infiltration system failure are to be minimized.

Institutional Components

The “BMP Golden Rule” states that stormwater BMPs should never be required unless the stormwater program includes components that will assure that the BMPs are correctly designed, approved, constructed, inspected, maintained,

Table 1. Results of Maryland Infiltration Practices Surveys

	Basins		Trenches		Dry Wells		Perv. Paving		Veg. Swale	
	1986	1990	1986	1990	1986	1990	1986	1990	1986	1990
# facilities	63	48	94	88	30	25	14	13	6	3
(% of total)	30%	27%	45%	30%	14%	14%	7%	7%	3%	2%
Facility Evaluations										
Functioning	30	18	75	47	23	18	7	2	3	2
	48%	38%	80%	53%	77%	72%	50%	15%	50%	67%
OM Needed	41	39	28	64	9	4	10	8	6	3
	65%	81%	30%	73%	30%	16%	71%	62%	100%	67%
Performance and Maintenance Criteria										
Buffer strip	20	4	65	35	24	0	14	3	1	0
inadequate	32%	8^	69%	39%	80%		100%	23%	17%	
Stabilization	12	23	11	13	1	3	1	1	3	1
needed	19%	48%	12%	15%	3%	12%	7%	8%	50%	33%
Sediment	24	28	32	58	0	2	9	9	4	1
entry	38%	58%	34%	66%		8%	64%	64%	67%	33%
Inappropriate	41	25	25	20	9	3	7	4	4	0
ponding	65%	52%	27%	23%	30%	12%	50%	31%	67%	
No observed	na	na	45	58	4	7	10	11	na	na
well			45%	56%	13%	28%	71%	85%		

and operated (Livingston, 1997). Specifically, the program must have stormwater treatment and management goals, performance standards, education, and an institutional framework that includes plan approval, inspections during and after construction, legal operation and maintenance entity requirements, effective compliance mechanisms, and dedicated funding mechanisms.

Program goals: Experience has shown that stormwater programs need to have multiple objectives that are important to the general public in order to gain the support of the community. Typically, these will include flood protection, erosion and sediment control during construction, water quality and habitat protection, and open space and recreation. Infiltration systems can help achieve all of these goals.

Performance standards: Nearly all stormwater treatment programs in the United States are technology-based, relying upon a performance standard (minimum level of treatment) and design criteria for various BMPs that assure that they achieve the desired treatment goal. A review of 32 stormwater programs around the country showed that the most common performance standard is removing at least 80% of the average annual loading of total suspended solids (WMI, 1997a). Some programs require higher levels of treatment for stormwater discharges to sensitive waters, such as Florida's requirement that discharges to Outstanding Florida Waters remove at least 95% of the average annual pollutant load. Technology-based performance standards such as these provide water quality goals for nonpoint sources that create equity with the minimum treatment requirements for domestic wastewater point sources (Livingston, 1988).

Institutional framework: The stormwater program must have a strong institutional framework that assures that all BMPs are (1) properly designed, (2) reviewed and approved, (3) inspected during and after construction, and (4) operated and maintained. The components of this institutional framework are set forth in Figure 1. One of the most important components especially for infiltration practices, is a feedback mechanism among system inspectors, plan reviewers, and designers about what is working and what is not. This information can then be used to revise the design criteria for infiltration BMPs and improve their potential for long-term success.

Technical Components:

Successful implementation of any BMP depends on a thorough understanding of the factors that determine the BMP's treatment effectiveness, a strong scientific basis for the BMP's design criteria, and an understanding of the site conditions that are required or that limit the utility of a specific BMP. Infiltration practices are also commonly called retention practices because they retain the runoff on-site and are designed to infiltrate a design volume (treatment volume) of stormwater. Factors that influence the treatment effectiveness and feasibility of infiltration practices include (1) precipitation patterns, (2) whether the system is designed as an on-line or off-line system, (3) whether pretreatment via the BMP treatment train is provided, and (4) site characterisitcs such as land use, soil type, geology, water table elevation, topography, and vegetation.

Infiltration areas, especially off-line ones, can be incorporated easily into landscaping or open space areas of a site. These can include natural or excavated grassed or landscaped depressions and recreational areas. Parking lots, with their landscape islands, offer an excellent opportunity for the use of this concept since even the infiltration of a quarter inch of runoff will greatly reduce sediments, metals, oils and greases. Placing storm sewer inlets within recessed parking lot landscape areas, raising the inlet a few inches above the bottom, and using curb cuts to allow runoff to enter this area represents a highly effective treatment train. If site conditions prevent the exclusive use of infiltration, then off-line retention areas should be used as pretreatment practices in a stormwater treatment train. This is especially true if detention lakes are the primary component of the stormwater system and the lakes are intended to serve as a focal point of the development.

Pollutant removal efficiency factors: Average annual pollutant removal efficiency is calculated considering the annual mass of pollutants available for discharge and the annual mass removed. The primary removal mechanism for infiltration practices is the volume of stormwater that is infiltrated, since this eliminates the discharge of stormwater and its associated pollutants. In addition, the system's vegetation and the surficial soils play an important role in binding and transforming pollutants as the water infiltrates. As with any type of stormwater management practice, actual field efficiency will depend on a large number of factors. For infiltration practices, such factors include:

1. Long-term precipitation characteristics; such as mean number of storms per year, their intensity and volume, and average inter-event time.

Figure 1. Stormwater Program Institutional Framework Components

Inspections
- Erosion/sediment controls
- Stormwater system construction
- Stormwater system operation

Stormwater system operation/maintenance
- Public facilities
- Private facilities
- Adopt a pond program

Plan review and approval
- Site plans
- Erosion control plans
- Stormwater plans
- Feedback evaluation process

Education programs
- General public
- Elected officials
- School curriculum
- Designers
- Developers
- Builders
- Practitioners
- Inspectors

Structural BMPs
- Design criteria
- Research/performance
- Proper construction
- Proper operation
- Maintenance

Administration
- Lead agency?
- Separate agency?

Staffing
- Engineers
- Inspectors
- Planners
- Scientists
- Maintenance
- Clerical

Compliance/enforcement
- Stop-work orders
- Fines
- Civil or criminal

Performance standards
- Peak discharge rate
- Volume
- Treatment

Nonstructural BMPs
- Site planning
- Source controls
- Land acquisition
- Street sweeping

Program Evaluation
- Citizen surveys
- Bldg. community surveys
- BMP monitoring
- Water body monitoring

Stormwater Retrofitting
- Watershed goal
- Targeting/prioritization
- Capital improvements
- Regional BMPs

Local land use plan | **Stormwater master planning** | **Watershed planning**

Integration with other federal, state, regional, and local programs

Adopt program laws/regulations | **Adopt stormwater utility ordinance/fees**

Legal	**Funding**	**Staffing**	**Public**	**Govt. Roles Responsibilities**

2. The occurrence of first flush, which is related to the amount of directly connected impervious area; type of stormwater conveyance system; and the pollutant of interest

3. Whether the system is an "on-line" or an "off-line" design

4. Cumulatively, the above three factors determine the minimum treatment volume and maximum storage recovery time

The U. S. Weather Bureau has measured weather statistics at many locations around the country. Long-term precipitation records, including such information as day and duration of event, intensity, volume, etc., are available from either the Federal government or private vendors. Statistical analysis of these records can develop probability frequencies for storm characteristics such as the mean storm volume and the mean inter-event period between storms.

"First flush" describes the washing action that stormwater has on accumulated pollutants in the watershed. In the early stages of runoff, the land surfaces, especially impervious ones like streets and parking areas, are flushed clean by the stormwater. This flushing creates a shock loading of pollutants. However, the occurrence and prevalence of first flush depends largely on precipitation patterns, the degree of imperviousness of the contributing drainage area, the size of the drainage area, and the type of stormwater conveyance system. Florida studies have determined that for highly impervious urban land uses with drainage areas under 100 acres, there is a first flush for many pollutants, especially particulates (Yousef et al., 1985; Miller, 1985). In areas such as Oregon and Washington, however, where rainfall consists of low intensity, long-duration "events," first flush is not very prevalent.

On-line stormwater practices store runoff temporarily before most of the volume is discharged to surface waters. These systems capture all of the runoff from a design storm. This mixes all stormwater within the system, thereby masking first flush and reducing pollutant removal. They primarily provide flood control benefits, with water quality benefits usually secondary--although on-line wet detention systems provide both.

Off-line practices are designed to divert the more polluted first flush stormwater for water quality treatment, isolating it from the remaining stormwater that is managed for flood control. In infiltration systems, the diverted first flush is not discharged to surface waters, but is stored until it is gradually removed by infiltration, evaporation, and evapotranspiration. Vegetation, such as grass in the bottom and sides of infiltration areas, helps to trap stormwater pollutants and reduce the potential for transfer of these pollutants to groundwater. Off-line retention practices are the most effective for water quality enhancement of stormwater.

Since an off-line retention area primarily provides for stormwater treatment, it must be combined with other BMPs for flood protection to form a comprehensive stormwater management system. Figure 2 is a schematic of an off-line system, commonly referred to as a "dual pond system." In these systems, a smart weir directs the first flush stormwater into the infiltration area until it is filled, with the remaining runoff being routed to the detention facility for flood control.

A more recent investigation of the influence of long-term rainfall characteristics on the efficiency of retention practices included inter-event dry periods, leading to the development of diversion volume curves for inter-event dry periods of varying length (Wanielista et al., 1991a). Figure 3 shows an example diversion volume curve for the Orlando area. It is important to note that first flush is not considered in these curves. If a first flush effect does exist, the design curves would be conservative in that the percent treatment efficiency of the infiltration system would increase. Furthermore, these curves are based on precipitation-interevent-frequency (PIF) curves that also include consideration of the probability that a storm greater than the design storm will occur. The PIF analysis looked at exceedance probabilities storms with a return period of 2, 3, 4, or 6 months, representing a chance that the storm will exceed the design volume 6, 4, 3, or 2 times per year. Other useful products from this project are Rate-Efficiency-Volume charts and curves that can be used to design wet detention ponds that reuse runoff and thereby help to balance pre- and post-development volume (Livingston et al., 1999).

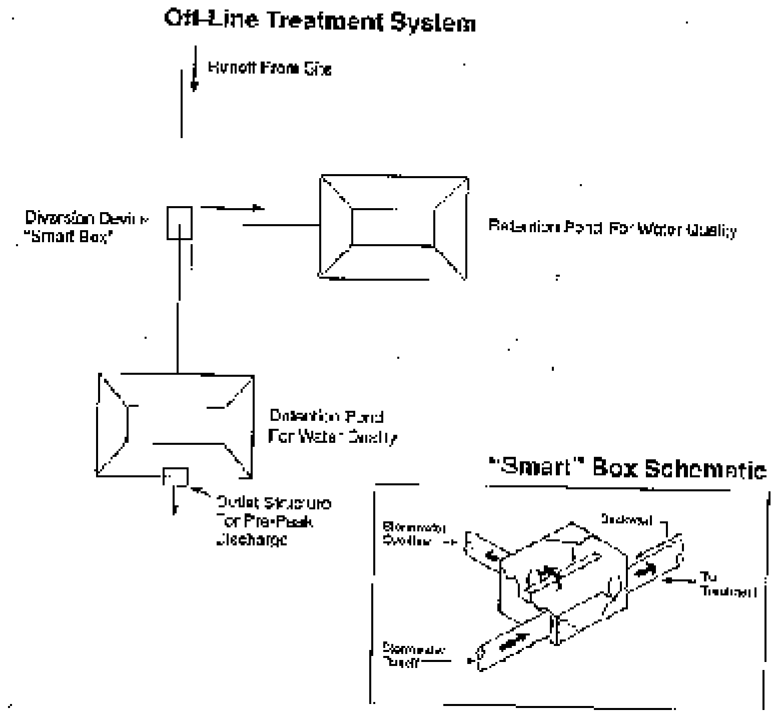

Figure 2. Schematic of an Off-line Stormwater System.

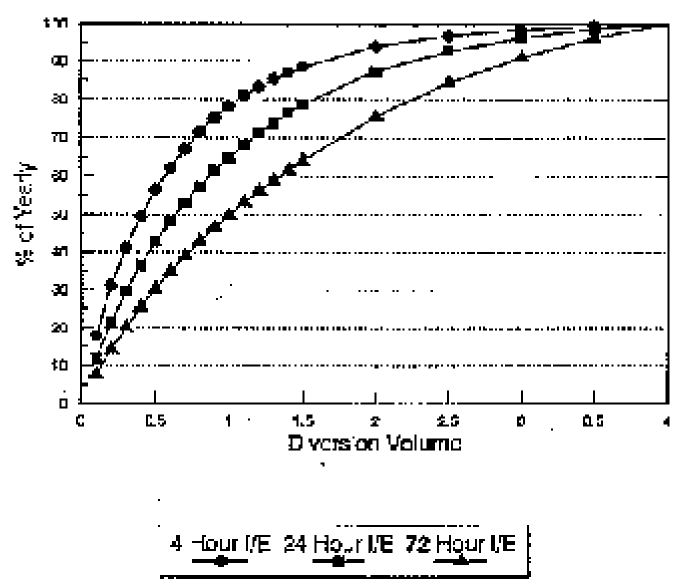

Figure 3. Diversion Volume Curve for Orlando, Florida.

Site Characteristics: The suitability of a site for using infiltration practices will depend on a careful evaluation of the site's natural attributes. Proposed infiltration areas should be evaluated for feasibility on any particular site or project by examining the following:

SOILS - Must be suitable for infiltration. Nationally, most states recommend that soil textures should not have more than 30% clay content or 40% silt content. Most importantly, they need to be able to percolate the diverted volume to infiltrate within 72 hours, or within 24-36 hours for infiltration areas that are planted with grasses. Therefore, soils that have been classified by the NRCS as HSG A are recommended for infiltration practices, although they can be successfully used with HSG B soil types.

INFILTRATION RATES - In recent years, the minimum permeability rate recommended for infiltration practices has been raised by implementing agencies. Shaver (1986) recommended a minimum rate of 0.25 inches per hour, but Maryland's regulations now recommend 0.52 inches per hour. One of the most difficult aspects of designing infiltration practices is obtaining reliable information about the actual infiltration rate of the soil where the practice will be constructed. Unfortunately, such information is not easily obtainable. Avellaneda (1985) conducted 20 hydrologic studies of vegetated swales constructed on sandy soils with a water table at least one foot below the bottom during dry conditions. Infiltration rates were measured using laboratory permeability tests, double ring infiltrometers, and field mass balance experiments. The field mass balance method measured a minimum infiltration rate of 2-3 inches/hour. This measured rate was much less than lab permeabilities, rates measured by double ring infiltrometer tests (5-20 in/hr), or rates published in the Detailed Soil Survey.

The following should be considered for determining the infiltration rate for retention practices:

1. Since the infiltration rate is the key to designing any retention practices, conservative estimates should be used, and safety factors incorporated into the design to ensure that the design volume will actually be percolated into the soil and not discharged downstream.

2. It is important that on-site infiltration measurements be taken at the locations where retention practices will be located. More importantly, since soil characteristics and infiltration rate change with depth, it is crucial that the measurements be made at the depth of the design elevation of the bottom of the retention practice.

3. Infiltration rates should be determined by mass balance field tests if possible. They provide the most realistic, accurate estimate of the percolation rate. If field tests are not possible, infiltrometer tests should be used, with lab permeability tests a third option. In either of these latter two tests, the design infiltration rate should be half of the lowest measured rate. As a last resort, information from Detailed Soil Surveys can be used to estimated the infiltration rate. However, the lowest rate should be used--as should a safety factor of two.

A recent assessment of infiltration practices in Carroll County, Maryland, quantified the infiltration rates for six basins and six trenches of differing ages (Nelson et al., 1999). They found that 64% of the systems had an average infiltration rate below the state's minimum recommended rate. However, 70% of the practices were still recovering their storage volume within the required 72 hours. Interestingly, for some facilities (mainly trenches), the infiltration rate met or exceeded the minimum state rate for a large percentage of the volume of water infiltrated, while the remaining water persisted for much longer periods of time before infiltrating. This may indicate that (1) the infiltration rate is related to the hydraulic head, where the higher depth of the stormwater in the BMP creates a higher pressure pushing water into the ground, or (2) the bottoms of the systems accumulate fines that impede percolation, while the sides of the systems are still infiltrating runoff rapidly.

WATER TABLE - The seasonal high water table should be at least three feet beneath the bottom of the infiltration area to assure that stormwater pollutants are removed by the vegetation, soil, and microbes before contacting the groundwater. Jacobson and Horner (1993) recommend a minimum of five feet if the seasonal high water table cannot be estimated accurately. When considering the groundwater elevation, it is important to remember that the retention area can cause a mounding effect on the water table, thereby raising it above the predevelopment level. The Southwest Florida Water Management District (SWFWMD) has developed a model that can be used to more accurately determine the seasonal high water table and the effects of mounding (SWFWMD, 1998).

GEOLOGY - Bedrock should be at least three feet beneath the bottom of the infiltration area. In those parts of the country where limestone is at or near the land surface, special precautions must be taken when using infiltration practices. The potential for groundwater contamination in such areas is quite high, especially in "Karst Sensitive Areas" (KSA) where sinkhole formation is common. In KSAs, solution pipe sinkholes may form in the bottom of infiltration areas creating a direct conduit for stormwater pollutants to enter the groundwater. Solution pipes often open in the bottom of retention areas because the natural soil plug capping the solution pipe is thinned by partial excavation to create the retention area and because the stormwater creates a hydraulic pressure which can wash out the plug.

In KSAs, a site-specific hydrogeologic investigation should be undertaken that includes geologic borings wherever infiltration areas are proposed and mapping limerock outcroppings and sinkholes on site. Infiltration systems in KSAs should (1) include several small off-site areas, (2) use swale conveyances for pretreatment, (3) be as shallow as possible, (4) be vegetated with a permanent cover such as sodded grasses, and (5) have flat bottoms to keep the stormwater spread out across the entire area.

TOPOGRAPHY - Infiltration practices should not be located on areas with slopes over 20% to minimize the chance of downstream water seepage from the subgrade. Sloping sites often require extensive cut and fill operations. Infiltration practices should not be sited on fill material, since fill areas are very susceptible to slope failure, especially when the interface of the fill/natural soil becomes saturated.

VEGETATION - To reduce the potential for stormwater pollutants to enter groundwater, and to help maintain the soil's capacity to absorb water, infiltration practices should be vegetated with appropriate native vegetation, especially grasses. However, this type of vegetation cannot tolerate long-term inundation, so the retention area must be capable of infiltrating all of its runoff within a relatively short time period (i.e., 24 to 36 hours). The design of “bioretention” systems incorporates soils and vegetation that are proficient in trapping stormwater pollutants within them and takes advantage of microbial processes that help transform and trap pollutants in the terrestrial environment.

SET BACKS - Infiltration areas should be located at least 100 feet from any water supply well and at least 12 feet down-gradient from any building foundations. Additionally, they should be set back at least 50 feet from on-site wastewater systems, especially drain fields.

LAND USE RESTRICTIONS - Certain infiltration practices can only be applied to particular land uses. For example, some sites are so small or intensively developed that space is insufficient for surficial practices (e.g., retention basin), but they may allow for infiltration or exfiltration trenches if pretreatment can be provided. A concern with any infiltration practice is the potential for hazardous or toxic wastes to enter the system and migrate into the groundwater. Land uses where such substances are used should implement comprehensive pollution prevention, spill containment, and emergency response plans that will prevent dangerous materials from getting into the infiltration system.

POTENTIAL FOR GROUNDWATER POLLUTION - A possible concern about infiltration practices is whether they simply are transferring the stormwater pollution problem from surface waters to groundwaters. Stormwater pollutants, especially heavy metals, quickly bind to soil particles and vegetation is effective in filtering pollutants, thereby minimizing the risk of groundwater contamination (Harper, 1985; Yousef et al, 1985b). However, groundwater beneath swales, and retention areas located in highly sandy soils with low organic content, did show elevated levels of heavy metals down to depths of 20 feet (Harper, 1988).

Design Criteria

Once all of the above factors have been quantified using state, regional, or local data as appropriate, specific design criteria can be established. Table 2 summarizes the design criteria for infiltration systems set forth in Florida’s stormwater regulations. St. John’s River Water Management District (SJRWMD, 1992).

Table 2. Florida's Design Criteria for Infiltration Practices

BMP	80% Treatment Effectiveness Diversion Volume
Swales	Infiltrate 80% of the runoff from a 3-yr, 1-hr storm (2.5 inches)
Retention - Off-line	Infiltrate the larger of 0.5 inches of runoff or 1.25" X % impervious
Retention - On-line	Infiltrate an additional 0.5 inches of runoff
DESIGN FACTOR	CRITERIA
Soil type	HSG A or B with < 30% clay or < 40% silt/clay
Treatment volume recovery time	72 hours, 24 to 36 hours if grassed
Water table or bedrock	At least 3 feet beneath bottom after mounding
Topography	On slopes < 20%, not on fill soils
Vegetation	Recommended to reduce potential for groundwater pollution and to maintain soil permeability
Land use	May not be appropriate at sites where hazardous materials spills may occur

Swales: Traditionally, swales are used primarily for stormwater conveyance and, as such, are considered an on-line practice. The removal of stormwater pollutants by swales can occur by infiltration or vegetative filtration. Investigations in Florida (Yousef et al., 1985a; Harper, 1985) have concluded that swale treatment efficiency largely depends on the volume of stormwater that can be infiltrated through the filtering vegetation and into the soil.

Avellaneda (1985) developed the following equation for a triangular-shaped swale to estimate the length of swale necessary to infiltrate the design stormwater treatment volume:

$$L = \frac{KQ^{5/8}S^{3/16}}{n^{3/8}i}$$

where:

L = swale length (m)
Q = average runoff flow rate (m3/S)
S = longitudinal slope (m/m)
K = constant which is a function of side slope that varies from 4,722 to 10,516
n = Mannings roughness coefficient
i = infiltration rate (cm/hr)

For most residential, commercial, and highway projects, the length of swales necessary to percolate the stormwater needed to achieve the 80% performance standard was found to be excessive, or at least twice the distance available. Thus, some type of swale block (berm) or on-line detention/retention may be more helpful. Swales make excellent pretreatment practices by providing for the infiltration of some stormwater and for some vegetative filtration. By using a raised storm sewer inlet, swales can provide water quality enhancement via retention and still serve as effective conveyances for flood protection. Swales can incorporate retention by using swale blocks, small check dams, or elevated driveway culverts to create storage; thereby reducing runoff velocity, reducing erosion, and promoting infiltration. In highway designs for high speed situations, safety must be considered; thus, a maximum depth of water equal to 1.5 feet and flow line slopes on the berms of 1 vertical/20 horizontal are recommended. Along lower speed highways or in some residential/commercial urban settings, steeper flow line berm slopes (1 on 6) are acceptable (Wanielista et.al., 1986).

Unlike Florida, investigations in Washington State (Horner, 1988; WPCD, 1992) indicate that swales can also act as a biofilter, with removal of particulate pollutants without infiltration of stormwater. The following recommendations were made to improve their water quality benefits:

1. Maximum design velocity should not exceed 27 cm per second.

2. A hydraulic residence time of at least 9 minutes is recommended for removal of about 80% of the total suspended solids. Longer residence times will provide higher removal effectiveness.

3. Swale width should be limited to 6 to 8 feet, unless special measures are provided to assure a level swale bottom, uniform flow spreading, and management of flows to prevent formation of low-flow channels.

4. Swale slopes should be between 2 and 4%.

5. Water depth should be limited to no greater than one half the height of the grass, up to a maximum of 3 inches of water depth.

6. Swale length will be a function of the hydraulic residence time, swale width, and stormwater volume and velocity.

Implementation Components

Even if effective design criteria have been established for an infiltration system, the design has been reviewed and approved, and the institutional framework to assure performance has been established, an infiltration system may still not work correctly. In fact, assessments of the success or failure of infiltration systems have determined that poor construction is a major factor in system failure (Pensyl and Clement, 1987; Lindsey et al., 1991). We will discuss five considerations that are essential to proper implementation of infiltration practices including (1) education, (2) erosion and sediment control, (3) construction, (4) inspections, and (5) maintenance.

Education: The stormwater program needs to include an extensive education program that targets BMP designers, plan reviewers, inspectors, contractors, and maintenance personnel. Each of these practitioners is an important part of the stormwater team. They must each understand their role in BMP design and implementation, as well as the technical factors discussed above. Additionally, a communication mechanism needs to be established among all of these practitioners so that in-the-field knowledge of what works, and what does not work, is transferred back to all other team members. With respect to BMP installation, the plan reviewers and inspectors should meet with the project engineers and contractors on-site to review the site plan, construction sequencing, erosion and sediment control plan and details, and the infiltration system's detailed standards and specifications.

Erosion and sediment control: Infiltration practices must be protected from sediment loadings, especially during the project's construction phases. Infiltration practices should never be used as part of the erosion and sediment control system, nor should they be put into operation until all contributing drainage areas are fully stabilized. Although sediment loads drop sharply after construction is completed, gradual clogging of infiltration practices can still occur. Pre-treatment practices such as swale conveyances or vegetated buffer strips can help to filter out sediments and extend the life of retention practices. Do not forget the treatment train concept.

Construction considerations: To prevent clogging of infiltration areas, special precautions must be taken during the entire construction phase of a project to prevent reduction of the system's infiltration capacity. In particular, two areas need to be stressed, including preventing sedimentation during construction and preventing compaction of the soil. Areas that are selected for infiltration use should be well marked during site surveying and protected during construction. Specifical construction recommendations are as follows (WMI, 1997b):

1. If possible, schedule construction so it does not occur during the rainy season but does occur during the vegetation growing season. For example, in Auckland, New Zealand, construction sites are shut down during the winter when long, prolonged rains make erosion and sediment controls ineffective and when vegetation does not

   grow well. Unfortunately, in the United States, these seasons often overlap and the economics of development dictate the time frame for starting construction.

2. Before the development site is graded, areas planned for use as infiltration systems should be well marked during site surveying, and all traffic and heavy equipment kept away from the area to prevent compacting the underlying soils.

3. Construction should be overseen by someone who is trained and experienced in the installation of infiltration practices, and who is knowledgeable about their purpose and operation.

4. The design team should inspect the exposed soil after excavation to confirm that soil conditions are as expected and are suitable for the approved design. If they are not, work should not proceed and the situation should be analyzed to determine whether or not design or construction changes should be made to the approved design.

5. Construction of the infiltration system should not begin until after the site has been completely stabilized. If this is not possible, then:

   a. Diversion berms should be placed around the perimeter of the infiltration area during all phases of construction to divert runoff and sediment away from it.

   b. Sediment and erosion control plans for the site should be oriented to keep sediment and runoff completely away from the area.

   c. The facility should not be excavated to final grade until after the contributing drainage area is stablilized. Leave at least two feet of native soil during the initial excavation.

6. Infiltration areas should never be used as a temporary sediment basins during the construction phase. Unfortunately, it is common for infiltration areas, especially basins, to be used as a sediment trap, with initial excavation to within two feet of the final design elevation of the basin floor. If the facility is to be used during construction, this soil can be removed in layers as it clogs. Once construction is completed, sediment that accumulated during the construction phase can then be removed when the basin undergoes final excavation to its design elevation. However, recent experience indicates that even with this type of construction practice, infiltration areas used as sediment traps have a higher rate of failure.

7. Infiltration areas/basins should be excavated using light earth-moving equipment with tracks or over-sized tires. Normal rubber tires should be avoided since they compact the subsoil and reduce its infiltration capabilities. For the same reason, the use of bulldozers or front end loaders should be avoided.

8. During construction, place excavated material at least 10-15 feet away from the infiltration area.

9. Since some compaction of the underlying soils is still likely to occur during excavation, the floor of the basin should be deeply tilled with a rotary tiller or disc harrow at the end of the excavation process.

10. Rock used in infiltration or exfiltration trenches should be washed clean of sediments. Rock should be placed in lifts and compacted after each lift.

11. Trenches should be clear of any protruding objects and carefully inspected before installing geotextile fabrics. The fabrics should have the proper permeability and be installed with at least a 12-inch overlap, in a shingle-like manner

12. Trenches should be covered and not put into operation until the contributing drainage area is completely stabilized and all pretreatment BMPs installed.

13. Pervious asphalt and concrete should be installed only by certified personnel who are specifically trained in their batching, pouring, and finishing.

14. The basin should be stabilized with vegetation within a week after construction. Use of low maintenance, rapidly germinating native grasses are recommended. The condition of the newly established vegetation should be checked several times over the first two months, and any necessary remedial actions taken (e.g., reseeding, fertilization, and irrigation).

Inspections: Like all stormwater treatment practices, infiltration systems need to be inspected during construction and on a regular basis after construction. Inspections during construction are needed to assure that the infiltration system is built in accordance with the approved design and standards and specifications. Five inspections are recommended: (1) pre-construction, (2) during excavation, (3) during construction of the embankment (if applicable), (4) after final excavation, and (5) after construction is completed. During this final inspection, the inspector should have a copy of the "As-built or record drawings." In addition, infiltration systems should be inspected semi-annually after construction (before and after wet seasons) to ensure that they continue to function. Two site trips are recommended: one during or immediately after a rainfall, so that conditions during operation can be observed, and a second from 24 to 72 hours after the rainfall, to determine whether the system is recovering its storage volume as designed. Inspection forms are highly recommended. Examples of inspection forms (WMI, 1997b) can be downloaded from the EPA web site located at http://www.epa.gov/owow/NPS/orderform.html.

Maintenance: All infiltration practices will require regular and non-routine maintenance to maintain their ability to infiltrate stormwater. The frequency and need for maintenance will depend primarily on the loading of particulates and whether pre-treatment practices have been employed. Routine maintenance includes revegetating eroding areas, removing materials that accumulate in pretreatment BMPs, and removing materials from inlets and outlets. Non-routine, restorative maintenance activities should be conducted whenever inspections reveal that stormwater remains in the system beyond the designed time. These may include structural repairs to the inlets or outlets and restoration of the infiltration capability of the system.

Additional Concerns and Recommendations

Concerns with Pervious Pavement: Local land development codes typically specify the type of material for a parking lot (i.e., paved, grass, gravel) and determine the number and size of parking spaces within a parking lot. These requirements should be reviewed carefully to ensure that they are necessary (is paving really required in every case) and that the number of spaces is related to actual traffic demands. After these requirements have been reviewed and verified, the use of pervious pavement within a parking lot should be examined. Pervious pavement materials include pervious asphalt, pervious concrete, turf blocks, and even Geoweb covered with sod.

Overall, experiences with pervious pavements have not been very good. Pervious pavements have been prone to clogging. Causes include poor erosion and sediment control during construction, unstabilized drainage areas after construction, improper mixing and finishing of the pavement, and poor maintenance. However, field investigations of pervious concrete that has been in use for up to 15 years in Florida indicate that these parking lots can continue to infiltrate rainfall and runoff if they were installed and maintained properly (FCMA, undated). Pervious concrete not only helps reduce site imperviousness, but also reduces hydroplaning and road noise.

Recommendations: Specific recommendations and other important information about infiltration systems that will help increase their successful implementation are summarized in Table 3. This table includes essential information about the advantages, disadvantages, maintenance, and other aspects of successfully using infiltration practice. To improve evaluation of site conditions for the suitability of infiltration practices, Jacobson and Horner (1993) recommended a quan titative rating system. The factors used in the system included: (1) soil till layer (presence and location), (2) location of seasonal high water table, (3) removal efficiency of the pretreatment BMPs, (4) degree of siltation protection, (5) soil type, and (6) infiltration rate. Different degrees of acceptability are possible: (1) disqualifying (characteristics that eliminate design or location from further consideration), (2) passable (characteristics that allow consideration but not ideal), and (3) ideal (optimum characteristics for design or siting of facility). Table 4 illustrates the proposed rating system factors.

Table 3. Additional Information About Infiltration Systems to Enhance Successful Implementation

Infiltration Bmp Type	Advantages	Disadvantages	Maintenance	Comments
Surface Basin (Typically recessed areas or, in Mid-Atlantic States, rock filled)	•Integrate into land-scaping, open space, parking lot islands •Use for recreation •Easier inspection and maintenance	•Land area required •Potential mosquito problem if not designed or maintained properly	•Vegetated basins should be mowed and clippings removed •Remove sediments when dry and cracked •Non-vegetated basins require annual disking	•Can serve larger drainage 3:1 or flatter side slopes, flat bottom •Bottom and side slope vege-tation recommended
Infiltration Trench (Typically a rock filled trench)	•Can be used where land or space is limited	•Easily clogged •Difficult to unclog •Difficult to monitor performance	•Removing sediments that accumulate in rocks	•Pretreatment essential •Use observation well •Keep covered until drainage area stabilized
Exfiltration Trench (Typically a perforated pipe with a gravel envelope)	•Can be used where land or space is limited	•Easily clogged •Difficult to unclog •Difficult to monitor performance	•Remove materials that enter pipe •High pressure wash perforated pipe •Removing sediments that Accumulate in rocks, replace rocks	•Pretreatment essential •Source controls useful •Geotextile is limiting infiltra-tion factor •Inf. rate 0.5"/hr if use sides and bottom •Inf. rate 1"/hr if use bottom
Pervious Pavement	•Reduces impervious-ness •Reduces hydroplaning and highway noise •Higher recharge rates	•Easily clogged •Lack of trained practitioners •Anaerobic conditions may develop in soils	•Regular vacuum street sweeping •High pressure cleaning •Drilling holes to restore infiltration •Replacement	•Proper batching and place-ment is crucial •Education programs needed for practitioners •Post signs to inform users and keep dir and mud out
Swale (Typically a shallow, grassed conveyance system)	•Can be incorporated into site 's landscaping/ open areas •Great car in BMP Train •Aesthetically pleasing	•Not for flood control •May "disappear" from residential back yards •May become depository for trash, yard wastes	•Mow and remove grass clippings •Hydroscope accumulated sediments and resod •Repair erosion areas	•Wet swales (wetland plants) work great too •Use swale blocks, raised driveway culverts to retain runoff

Table 4. Possible Rating System to Evaluate the Suitability of Infiltration BMPs

Factor	Disqualifying Characteristic	Passable Characteristic	Ideal Characteristic
Soil till layer	Impenetrable, thick layer near surface	Layer present but at >5' depth, or easily penetrable	No till layer present
Seasonal High Water Table	Close to surface, within 5'	At intermediate depth, at least 5' below BMP bottom	Very deep, well below BMP bottom
Pretreatment	None provided	Some,minimum 50% TSS removal	Pretreatment provides >80% TSS removal
Siltation Protection	None provided	Any silt or construction sediment removed before final BMP construction	Fully protected from silt during construction
Soils	Saturated or with >30% clay or >40% silt/clay content	Coarse, highly infiltrative soil that can be modified to produce proper inf. rate	Loam or loamy sand
Infiltration Rate	<0.5"/hr	>2.5"/hr but with very deep water table or modified to slower rate	0.5 to 2.5"/hr

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Potential New Tools for the Use of Tracers to Indicate Sources of Contaminants to Storm Drainage Systems

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Abstract

This paper is a description of previously developed methods used to identify sources of contaminants in storm drainage systems, plus a review of emerging techniques that may also be useful. The original methods, along with selected new procedures, were tested using almost 700 stormwater samples collected from telecommunication manholes from throughout the U.S. About 10% of the samples were estimated to be contaminated with sanitary sewage, using these methods, similar to what is expected for most stormwater systems. The original methods are still recommended as the most useful procedure for identifying contamination of storm drainage systems, with the possible addition of specific tests for *E. coli* and enterococci and UV absorbance at 228 nm. Most newly emerging methods require exotic equipment and unusual expertise and are therefore not very available, especially at low cost and with fast turn-around times for the analyses. These emerging methods may therefore be more useful for special research projects than for routine screening of storm drainage systems.

Introduction

Urban stormwater runoff includes waters from many other sources which find their way into storm drainage systems, besides from precipitation. There are cases where pollutant levels in storm drainage are much higher than they would otherwise be because of excessive amounts of contaminants that are introduced into the storm drainage system by various non-stormwater discharges. Additionally, baseflows (during dry weather) are also common in storm drainage systems. Dry-weather flows and wet-weather flows have been monitored during numerous urban runoff studies. These studies have found that discharges observed at outfalls during dry weather were significantly different from wet-weather discharges and may account for the majority of the annual discharges for some pollutants of concern from the storm drainage system.

There have been numerous methods used to investigate inappropriate discharges to storm drainage systems. Pitt, *et al.* (1993) and Lalor (1994) reviewed many of these procedures and developed a system that municipalities could use for screening outfalls in residential and commercial areas. They are currently updating these earlier methods under funding from the U.S. EPA and the University of New Orleans. In these areas, sewage contamination, along with low-rate discharges from small businesses (especially laundries, vehicle repair shops, plating shops, etc.) are of primary concern. One of the earliest methods used to identify sewage contamination utilized the ratio of fecal coliform to fecal strep. bacteria. This method is still in use, but unfortunately has proven inaccurate in most urban stormwater applications The following discussion reviews the methodology developed by Pitt, *et al.* (1993) and Lalor (1994), and some new approaches that were investigated.

Use of Tracers to Identify Sources of Contamination in Urban Drainage Systems

This research investigated inappropriate discharges into storm drainage systems. It was of most concern to identify toxic or pathogenic sources of water, typically raw sewage or industrial wastewaters, that were being discharged accidentally into the storm drainage system.

Investigations designed to determine the contribution of urban stormwater runoff to receiving water quality problems have led to a continuing interest in inappropriate connections to storm drainage systems. Urban stormwater runoff is traditionally defined as that portion of precipitation which drains from city surfaces and flows via natural or man-made drainage systems into receiving waters. In fact, urban stormwater runoff also includes waters from many other sources which find their way into storm drainage systems. Sources of some of this water can be identified and accounted for by examining current National Pollutant Discharge Elimination System (NPDES) permit records for permitted industrial wastewaters that can be legally discharged to the storm drainage system. However, most of the water comes from other sources, including illicit and/or inappropriate entries to the storm drainage system. These entries can account for a significant amount of the pollutants discharged from storm sewerage systems (Pitt and McLean 1986).

Permits for municipal separate storm sewers include a requirement to effectively prohibit problematic non-stormwater discharges, thereby placing emphasis on the elimination of inappropriate connections to urban storm drains. Section 122.26 (d)(l)(iv)(D) of the rule specifically requires an initial screening program to provide means for detecting high levels of pollutants in dry weatherflows, which should serve as an indicator of illicit connections to the storm sewers. To facilitate the application of this rule, the EPA's Office of Research and Development's Storm and Combined Sewer Pollution Control Program and the Environmental Engineering & Technology Demonstration Branch, along with the Office of Water's Nonpoint Source Branch, supported research for the investigation of inappropriate entries to storm drainage systems (Pitt, et *al.* 1993). The approach presented in this research was based on the identification and quantification of clean baseflow and the contaminated components during dry weather. If the relative amounts of these components are known, the importance of the dry weather discharge can be determined.

The ideal tracer to identify major flow sources should have the following characteristics:

- Significant difference in concentrations between possible pollutant sources;
- Small variations in concentrations within each likely pollutant source category;
- A conservative behavior (i.e., no significant concentration change due to physical, chemical or biological processes); and,
- Ease of measurement with adequate detection limits, good sensitivity and repeatability.

In order to identify tracers meeting the above criteria, literature characterizing potential inappropriate entries into storm drainage systems was examined. Several case studies that identified procedures used by individual municipalities or regional agencies were also examined.

Parameters Suitable for Indicators of Contamination by Sanitary Sewage

Tracer Characteristics of Local Source Flows. Table 1 is a summary of tracer parameter measurements for Birmingham, Alabama. This table is a summary of the "library" that describes the tracer conditions for each potential source category. The important information shown on this table includes the median and coefficient of variation (COV) values for each tracer parameter for each source category. Appropriate tracers are characterized by having significantly different concentrations in flow categories that need to be distinguished. In addition, effective tracers also need low COV values within each flow category. The study indicated that the COV values were quite low for each category, with the exception of chlorine, which had much greater COV values. Chlorine is therefore not recommended as a quantitative tracer to estimate the flow components. Similar data must be collected in each community where these procedures are to be used. Recommended field observations include color, odor, clarity, presence of floatables and deposits, and rate of flow, in addition to the selected chemical measurements.

Simple Data Evaluation Methods to Indicate Sources of Contamination

Indicators Implying Contamination. Indicators of contamination (negative indicators) are clearly apparent visual or physical parameters indicating obvious problems and are readily observable at the outfall during the field screening

Table 1. Tracer Concentrations Found in Birmingham, Alabama, Waters (Mean, Standard Deviation and Coefficient of Variation)

	Spring water	Treated potable water	Laundry wastewater	Sanitary wastewater	Septic tank effluent	Car wash water	Radiator water
Fluorescence	6.8	4.6	1020	250	430	1200	22,000
(% scale)	2.9	0.35	125	50	100	130	950
	0.43	0.08	0.12	0.20	0.23	0.11	0.04
Potassium	0.73	1.6	3.5	6.0	20	43	2800
(mg/L)	0.070	0.059	0.38	1.4	9.5	16	375
	0.10	0.04	0.11	0.23	0.47	0.37	0.13
Ammonia	0.009	0.028	0.82	10	90	0.24	0.03
(mg/L)	0.016	0.006	0.12	3.3	40	0.066	0.01
	1.7	0.23	0.14	0.34	0.44	0.28	0.3
Ammonia/Potassium	0.011	0.018	0.24	1.7	5.2	0.006	0.011
(ratio)	0.02	0.006	0.050	0.52	3.7	0.005	0.011
	2.0	0.35	0.21	0.31	0.71	0.86	1.0
Fluoride	0.031	0.97	33	0.77	0.99	12	150
(mg/L)	0.027	0.014	13	0.17	0.33	2.4	24
	0.87	0.02	0.38	0.23	0.33	0.20	0.16
Toxicity	<5	47	99.9	43	99.9	99.9	99.9
(% light decrease after	n/a	20	<1	26	<1	<1	<1
25 minutes, I_{25})	n/a	0.44	n/a	0.59	n/a	n/a	n/a
Surfactants	<0.5	<0.5	27	1.5	3.1	49	15
(mg/L as MBAS)	n/a	n/a	6.7	1.2	4.8	5.1	1.6
	n/a	n/a	0.25	0.82	1.5	0.11	0.11
Hardness	240	49	14	140	235	160	50
(mg/L)	7.8	1.4	8.0	15	150	9.2	1.5
	0.03	0.03	0.57	0.11	0.64	0.06	0.03
pH	7.0	6.9	9.1	7.1	6.8	6.7	7.0
(pH units)	0.05	0.29	0.35	0.13	0.34	0.22	0.39
	0.01	0.04	0.04	0.02	0.05	0.03	0.06
Color	<1	c l	47	38	59	220	3000
(color units)	n/a	n/a	12	21	25	78	44
	n/a	n/a	0.27	0.55	0.41	0.35	0.02
Chlorine	0.003	0.88	0.40	0.014	0.013	0.070	0.03
(mg/L)	0.005	0.60	0.10	0.020	0.013	0.080	0.016
	1.6	0.68	0.26	1.4	1.0	1.1	0.52
Specific conductivity	300	110	560	420	430	485	3300
(µS/cm)	12	1.1	120	55	311	29	700
	0.04	0.01	0.21	0.13	0.72	0.06	0.22
Number of samples	10	10	10	36	9	10	10

activities. These observations are very important during the field survey because they are the simplest method of identifying grossly contaminated dry-weather outfall flows. The direct examination of outfall characteristics for unusual conditions of flow, odor, color, turbidity, floatables, deposits/stains, vegetation conditions, and damage to drainage structures is therefore an important part of these investigations. Table 2 presents a summary of these indicators, along with narratives of the descriptors to be selected in the field.

Table 2. Interpretations of Physical Observation Parameters and Likely Associated Flow Sources

Odor - Most strong odors, especially gasoline, oils, and solvents, are likely associated with high responses on the toxicity screening test. Typical obvious odors include: gasoline, oil, sanitary wastewater, industrial chemicals, decomposing organic wastes, etc.
sewage: smell associated with stale sanitary wastewater, especially in pools near outfall.
sulfur ("rotten eggs"): industries that discharge sulfide compounds or organics (meat packers, canneries, dairies, etc.).
oil and gas: petroleum refineries or many facilities associated with vehicle maintenance or petroleum product storage.
rancid-sour: food preparation facilities (restaurants, hotels, etc.).

Color - Important indicatorof inappropriate industrial sources. Industrial dry-weather discharges may be of any color, but darkcolors, such as brown, gray, or black, are usually of most common.
yellow: chemical plants, textile and tanning plants.
brown: meat packers, printing plants, metal works, stone and concrete, fertilizers, and petroleum refining facilities.
green: chemical plants, textile facilities.
red: meat packers.
gray: dairies.

Turbidity - Often affected by the degree of gross contamination. Dry-weather industrial flows with moderate turbidity can be cloudy, while highly turbid flows can be opaque. High turbidity is often a characteristic of undiluted dry-weather industrial discharges.
cloudy: sanitary wastewater, concrete or stone operations, fertilizer facilities, automotive dealers.
opaque: food processors, lumber mills, metal operations, pigment plants.

Floatable Matter - A contaminated flow may contain floating solids or liquids directly related to industrial or sanitary wastewater pollution. Floatables of industrial origin may include animal fats, spoiled food, oils, solvents, sawdust, foams, packing materials, or fuel.
oil sheen: petroleum refineries or storage facilities and vehicle service facilities.
sewage: sanitary wastewater.

Deposits and Stains - Refer to any type of coating near the outfall and are usually of a dark color. Deposits and stains often will contain fragments of floatable substances. These situations are illustrated by the grayish-black deposits that contain fragments of animal flesh and hair which often are produced by leather tanneries, or the white crystalline powder which commonly coats outfalls due to nitrogenous fertilizer wastes.
sediment construction site erosion.
oily petroleum refineries or storage facilities and vehicle service facilities.

Vegetation -Vegetation surrounding an outfall may show the effects of industrial pollutants. Decaying organic materials coming from various food product wastes would cause an increase in plant life, while the dischargeof chemical dyes and inorganicpigmentsfrom textile mills could noticeably decrease vegetation. It is important not to confuse the adverse effects of high stormwater flows on vegetation with highly toxic dry-weather intermittent flows.
excessive *growth:* food product facilities.
inhibited growth: high stormwater flows, beverage facilities, printing plants, metal product facilities, drug manufacturing, petroleum facilities, vehicle service facilities and automobile dealers.

Damage to Outfall Structures - Another readily visible indication of industrial contamination. Cracking, deterioration, and spalling of concrete or peeling of surface paint, occurring at an outfall are usually caused by severely contaminated discharges, usually of industrial origin. These contaminants are usually very acidic or basic in nature. Primary metal industries have a strong potential forcausing outfall structural damage because their batch dumps *are* highly acidic. Poor construction, hydraulic scour, and old age may also adversely affect the condition of the outfall structure.
concrete cracking: industrial flows
concrete spalling: industrial flows
peeling paint industrial flows
metal corrosion: industrial flows

Correlation tests were conducted to identify relationships between outfalls that were known to have severe contamination problems and the negative indicators (Lalor 1994). Pearson correlation tests indicated that high turbidity and obvious odors appeared to be the most useful physical indicators of contamination when contamination was defined by toxicity and the presence of detergents. High turbidity was noted in 74% of the contaminated source flow samples, This represented a 26% false negative rate (indication of no contamination when contamination actually exists), if one relied on turbidity alone as an indicator of contamination. High turbidity was noted in only 5% of the uncontaminated source flow samples. This represents the rate of false positives (indication of contamination when none actually exists) when relying on turbidity alone. Noticeable odor was indicated in 67% of flow samples from contaminated sources, but in none of the flow samples from uncontaminated sources. This translates to 37% false negatives, but no false positives. Obvious odors identified included gasoline, oil, sewage, industrial chemicals or detergents, decomposing organic wastes, etc.

False negatives are more of a concern than a reasonable number of false positives when working with a screening methodology. Screening methodologies are used to direct further, more detailed investigations. False positives would be discarded after further investigation. However, a false negative during a screening investigation results in the dismissal of a problem outfall for at least the near future. Missed contributors to stream contamination may result in unsatisfactory in-stream results following the application of costly corrective measures elsewhere.

The method of using physical characteristics to indicate contamination in outfall flows does not allow quantifiable estimates of the flow components and, if used alone, will likely result in many incorrect determinations, especially false negatives. These simple characteristics are most useful for identifying gross contamination: only the most significantly contaminated outfalls and drainage areas would therefore be recognized using this method.

Detergents as Indicators of Contamination. Results from the Mann-Whitney U tests (Lalor 1994) indicated that samples from any of the dry-weather flow sources could be correctly classified as clean or contaminated based only on the measured value of any one of the following parameters: detergents, color, or conductivity. Color and high conductivity were present in samples from clean sources as well as contaminated sources, but their levels of occurrence were significantly different between the two groups. If samples from only one source were expected to make up outfall flows, the level of color or conductivity could be used to distinguish contaminated outfalls from clean outfalls. However, since multi-source flows occur, measured levels of color or conductivity could fall within acceptable levels because of dilution, even though a contaminating source was contributing to the flow. Detergents, on the other hand, can be used to distinguish between clean and contaminated outfalls simply by their presence or absence, using a detection limit of 0.06 mg/L. All samples analyzed from contaminated sources contained detergents in excess of this amount (with the exception of three septage samples collected from homes discharging only toilet flushing water). No clean source samples were found to contain detergents. Contaminated sources would be detected in mixtures with uncontaminated waters if they made up at least 10% of the mixture.

Flow Chart for Most Significant Flow Component Identification. A further refinement is the flow chart shown on Figure 1. This flow chart describes an analysis strategy which may be used to identify the major component of dry-weather flow samples in residential and commercial areas. This method does not attempt to distinguish among all potential sources of dry-weather flows identified earlier, but rather the following four major groups of flow are identified: (1) tap waters (including domestic tap water, irrigation water and rinse water), (2) natural waters (spring water and shallow ground water), (3) sanitary wastewaters (sanitary sewage and septic tank discharge), and (4) wash waters (commercial laundry waters, commercial car wash waters, radiator flushing wastes, and plating bath wastewaters). The use of this method would not only allow outfall flows to be categorized as contaminated or uncontaminated, but would allow outfalls carrying sanitary wastewaters to be identified. These outfalls could then receive highest priority for further investigation leading to source control. This flow chart was designed for use in residential and/or commercial areas only.

In residential and/or commercial areas, all outfalls should be located and examined. The first indicator is the presence or absence of dry-weather flow. If no dry-weather flow exists at an outfall, then indications of intermittent flows must be investigated, Specifically, stains, deposits, odors, unusual stream-side vegetation conditions, and damage to outfall structures can all indicate intermittent non-stormwater flows. However, frequent visits to outfalls over long time periods, or the use of other monitoring techniques, may be needed to confirm that only stormwater flows occur. If intermittent flow is not indicated, then the outfall probably does not have a contaminated non-stormwater source. The other points on the flow chart serve to indicate if a major contaminating source is present, or if the water is uncontaminated. Component contributions cannot be quantified using this method, and only the “most contaminated” type of source present will be identified.

If dry-weather flow exists at an outfall, the flow should be sampled and tested for detergents. If detergents are not present, the flow is probably from a non-contaminated non-stormwater source. The lower limit of detection for detergent should be about 0.06 mg/L.

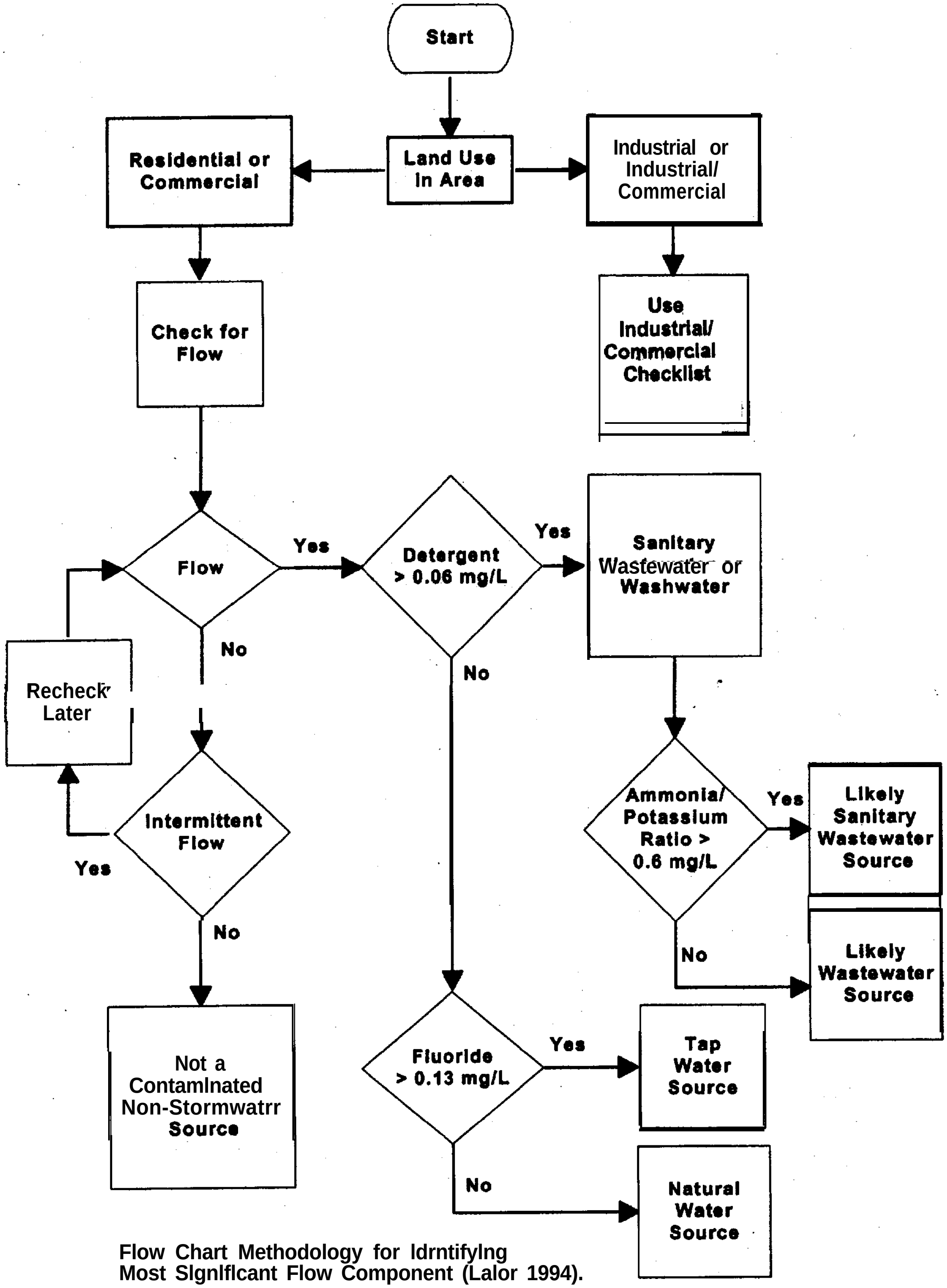

Figure 1. Simple Flow Chart Method to Identify Significant Contaminating Sources

If detergents are not present, fluoride levels can be used to distinguish between flows with treated watersources and flows with natural sources in communities where water supplies are fluoridated and natural fluoride levels are low. In the absence of detergents, high fluoride levels would indicate a potable water line leak, irrigation water, or wash/rinse water. Low fluoride levels would indicate waters originating from springs or shallow groundwater. Based on the flow source samples tested in this research (Table 1), fluoride levels above 0.13 mg/L would most likely indicate that a tap water source was contributing to the dry-weather flow in the Birmingham, Alabama, study area.

If detergents are present, the flow is probably from a contaminated non-stormwater source, as indicated on Table 1. The ratio of ammonia to potassium can be used to indicate whether or not the source is sanitary wastewater. Ammonia/potassium ratios greater than 0.60 would indicate likelysanitarywastewater contamination. Ammonia/potassium ratios were above 0.9 for all septage and sewage samples collected in Birmingham (values ranged from 0.97 to 15.37, averaging 2.55). Ammonia/potassium ratios for all othersamplescontaining detergents were below 0.7, ranging from 0.00 to 0.65, averaging 0.11. One radiator waste sample had an ammonia/potassium ratio of 0.65.

Non-contaminated samples collected in Birmingham had ammonia/potassium ratios ranging from 0.00 to 0.41, with a mean value of 0.06 and a median value of 0.03. Using the mean values for non-contaminated samples (0.06) and sanitary wastewaters (2.55), flows comprised of mixtures containing at least 25% sanitary wastes with the remainder of the flow from uncontaminated sources would likely be identified as sanitary wastewaters using this method. Flows containing smaller percent contributions from sanitary wastewaters might be identified as having a wash water source, but would not be identified as uncontaminated.

Emerging Tools for Identifying Sources of Discharges

Coprostanol and Other Fecal Sterol Compounds Utilized as Tracers of Contamination by Sanitary Sewage. A more likely indicator of human wastes than fecal coliforms and other "indicator" bacteria may be the use of certain molecular markers, specifically the fecal sterols, such as coprostanol and epicoprostanol (Eaganhouse, *eta/.* 1988). However, these compounds are also discharged by other carnivores in a drainage (especially dogs). A number of research projects have used these compounds to investigate the presence of sanitary sewage contamination. The most successful application may be associated with sediment analyses instead of water analyses. As an example, water analyses of coprostanol are difficult due to the typically very low concentrations found, although the concentrations in many sediments are quite high and much easier to quantify. Unfortunately, the long persistence of these compounds in the environment easily confuses recent contamination with historical or intermittent contamination.

Particulates and sediments collected from coastal areas in Spain and Cuba receiving municipal sewage loads were analyzed by Grimalt, *et a/.* (1990) to determine the utility of coprostanol as a chemical marker of sewage contamination. Coprostanol can not by itself be attributed to fecal matter inputs. However, relative contributions of steroid components can be a useful indicator. When the relative concentrations of coprostanol and coprostanone are higher than their 5? epimers, or more realistically, other sterol components of background or natural occurrence, it can provide useful information.

Sediment cores from Santa Monica Basin, CA, and effluent from two local municipal wastewater discharges were analyzed by Venkatesan and Kaplan (1990) for coprostanol to determine the degree of sewage addition to sediment. Coprostanols were distributed throughout the basin sediments in association with fine particles. Some stations contained elevated levels, either due to their proximity to outfalls or because of preferential advection of fine-grained sediments. A noted decline of coprostanols relative to total sterols from outfalls seaward indicated dilution of sewage by biogenic sterols.

Other chemical compounds have been utilized for sewage tracer work. Saturated hydrocarbons with 16-l 8 carbons, and saturated hydrocarbons with 16-21 carbons, in addition to coprostanol, were chosen as markers for sewage in water, particulate, and sediment samples near the Cocoa, FL, domestic wastewater treatment plant (Holm and Windsor, 1990). The concentration of the markers was highest at points close to the outfall pipe and diminished with distance. However the concentration of Cl 6-C21 compounds was high at a site 800 m from the outfall indicating that these compounds were unsuitable markers for locating areas exposed to the sewage plume. The concentrations for the other markers were very low at this station.

The range of concentrations of coprostanol found in sediments and mussels of Venice; Italy, were reported by Sherwin, *et al.* (1993). Raw sewage is still discharged directly into the Venice lagoon. Coprostanol concentrations were determined in sediment and mussel samples from the lagoon using gas chromatography/mass spectroscopy. Samples were collected in interior canals and compared to open-bay concentrations. Sediment concentrations ranged from 0.2-41 .0 µg/g (dry weight). Interior canal sediment samples averaged 16 µg/g compared to 2 µg/g found in open bay sediment samples. Total coprostanol concentrations in mussels ranged from 80 to 620 ng/g (wet weight). No mussels were found in the four most polluted interior canal sites.

Nichols, *et al.* (1996) also examined coprostanol in stormwater and the sea-surface microlayer to distinguish human versus nonhuman sources of contamination. Other steroid compounds in sewage effluent were investigated by Routledge, *et al.* (1998) and Desbrow, *et al.* (1998) who both examined estrogenic chemicals. The most common found were 17β-Estradiol and estrone which were detected at concentrations in the tens of nanograms per liter range. These were identified as estrogenic through a toxicity identification and evaluation approach, where sequential separations and analyses identified the sample fractions causing estrogenic activity using a yeast-based estrogen screen. GC/MS was then used to identify the specific compounds.

Estimating Potential Sanitary Sewage Discharges into Storm Drainage and Receiving Waters using Detergent Tracer Compounds. As described above, detergent measurements (using methylene blue active substance, MBAS, test methods) were the most successful individual tracer to indicate contaminated water in storm sewerage dry-weather flows. Unfortunately, the MBAS method uses hazardous chloroform for an extraction step. Different detergent components, especially Iinearalkylbenzene sulphonates (LAS) and linear alkylbenzenes (LAB), have also been tried to indicatesewage dispersal patterns in receiving waters. Boron, a major historical ingredient of laundry chemicals, can also potentially be used. Boron has the great advantage of being relatively easy to analyze using portable field test kits, while LAS requires chromatographic equipment. LAS can be measured using HPLC with fluorescent detection, after solid phase extraction, to very low levels. Fujita, *et a/.* (1998) developed an efficient enzyme-linked immunosorbent assay (ELISA) for detecting LAS at levels from 20 to 500 µg/L.

LAS from synthetic surfactants (Terzic and Ahel 1993) which degrade rapidly, as well as nonionic detergents (Zoller, *et a/.* 1991) which do not degrade rapidly, have been utilized as sanitary sewage markers. LAS was quickly dispersed from wastewater outfalls except in areas where wind was calm. In these areas LAS concentrations increased in freshwater but were unaffected in saline water. After time, the lower alkyl groups were mostly found, possibly as a result of degradation or settling of longer alkyl chain compounds with sediments. Chung, *et a/.* (1995) also describe the distribution and fate of LAS in an urban stream in Korea. They examined different LAS compounds having carbon ratios of Cl 2 and Cl 3 compared to Cl 0 and Cl 1, plus ratios of phosphates to MBAS and the internal to external isomer ratio (l/E) as part of their research. Gonález-Mazo, *et al.* (1998) examined LAS in the Bay of Cádiz off the southwest of Spain. They found that LAS degrades rapidly (Fujita, *et al.,* 1998, found that complete biodegradation of LAS requires several days), and is also strongly sorbed to particulates. In areas close to shore and near the untreated wastewater discharges, there is significant vertical stratification of LAS: the top 3 to 5 mm of water had LAS concentrations about 100 times greater than found at 0.5 m.

Zeng and Vista (1997) and Zeng, *et al.* (1997) describe a study off of San Diego where LAB was measured, along with polycyclic aromatic hydrocarbons (PAHs) and aliphatic hydrocarbons (AHs) to indicate the relative pollutant contributions of wastewater from sanitary sewage, nonpoint sources, and hydrocarbon combustion sources. They developed and tested several indicator ratios (alkyl homologue distributions and parent compound distributions) and examined the ratio of various PAHs (such as phenanthrene to anthracene, methylphenanthrene to phenanthrene, fluoranthene to pyrene, and benzo(a)anthracene to chrysene) as tools for distinguishing these sources. They concluded that LABs are useful tracers of domestic waste inputs to the environment due to their limited sources. They also describe the use of the internal to external isomer ratio (l/E) to indicate the amount of biodegradation that may have occurred to the LABs. They observed concentrations of total LABs in sewage effluent of about 3 µg/L, although previous researchers have seen concentrations of about 150 µg/L in sewage effluent from the same area.

The fluorescent properties of detergents have also been used as a tracer by investigating the fluorescent whitening agents (FWAs), as described by Poiger, *et a/.* (1996) and Kramer, *et a/.* (1996). HPLC with fluorescence detection was used in these studies to quantify very low concentrations of FWAs. The two most frequently used FWAs in household detergents (DSBP and DAS 1) were found at 7 to 21 µg/L in primary sewage effluent and at 3 to 9 µg/L in secondary effluent. Raw sewage contains about 10 to 20 µg/L FWAs. The removal mechanisms in sewage treatment processes is by adsorption to activated sludge. The type of FWAs varies from laundry applications to textile finishing and paper production, making it possible to identify sewage sources. The FWAs were found in river water at 0.04 to 0.6 µg/L. The FWAs are not easily biodegradable but they are readily photodegraded. Photodegradation rates have been reported to be about 7% for DSBP and 71% for DAS 1 in river water exposed to natural sunlight, after one hour exposure. Subsequent photodegradation is quite slow.

Other Compounds Found in Sanitary Sewage that may be used for Identifying Contamination by Sewage. Halling-Sorensen, *eta/.* (1998) detected numerous pharmaceutical substances in sewage effluents and in receiving waters. Their work addressed human health concerns of these low level compounds that can enter downstream drinking water supplies. However, the information can also be possibly used to help identify sewage contamination. Most of the research has focused on clofibric acid, a chemical used in cholesterol lowering drugs. It has been found in concentrations ranging from 10 to 165 ng/L in Berlin drinking water samples. Other drugs commonly found include aspirin, caffeine, and ibuprofen. Current FDA guidance mandates that the maximum concentration of a substance or its active metabolites at the point of entry into the aquatic environment be less than 1 µg/L (Hun 1998).

Caffeine has been used as an indicator of sewage contamination by several investigators (Shuman and Strand 1996). The King County, WA, Water Quality Assessment Project is examining the impacts of CSOs on the Duwamish River and Elliott Bay. They are using both caffeine (representing dissolved CSO constituents) and coprostanol (representing particulate bound CSO constituents), in conjunction with heavy metals and conventional analyses, to help determine the contribution of CSOs to the river. The caffeine is unique to sewage, while coprostanol is from both humans and carnivorous animals and is therefore also in stormwater. They sampled upstream of all CSOs, but with some stormwater influences, 100 m upstream of the primary CSO discharge (but downstream of other CSOs), within the primary CSO discharge line, and 100 m downriver of the CSO discharge location. The relationship between caffeine and coprostanol was fairly consistent for the four sites (coprostanol was about 0.5 to 1.5 µg/L higher than caffeine). Similar patterns were found among metals; chromium was always the lowest and zinc was the highest. King Co. is also using clean transported mussels placed in the Duwamish River to measure the bioconcentration potential of metal and organic toxicants and the effects of the CSOs on mussel growth rates (after 6 weekexposure periods). Paired reference locations are available near the areas of deployment, but outside the areas of immediate CSO influence. *US Water* News (1998) also described a study in Boston Harbor that found caffeine at levels of about 7 µg/L in the harbor water. The caffeine content of regular coffee is about 700 mg/L, in contrast.

Kratch (1997) summarized several investigations on cataloging the DNA of *E. co/i* to identify their source in water. This rapidly emerging technique seems to have great promise in addressing a number of nonpoint source water pollution issues. The procedure, developed at the Virginia Polytechnic Institute and State University, has been used in Chesapeake Bay. In one example, it was possible to identify a large wild animal population as the source of fecal coliform contamination of a shellfish bed, instead of suspected failing septic tanks. DNA patterns in fecal coliforms vary among animals and birds, and it is relatively easy to distinguish between human and non-human sources of the bacteria. However, some wild animals have DNA patterns that are not easily distinguishable. Some researchers question the value of *E. coli* DNA fingerprinting believing that there is little direct relationship between *E. co/i* and human pathogens. However, this method should be useful to identify the presence of sewage contamination in stormwater or in a receiving water.

One application of the technique, as described by Krane, *et a/.* (1999) of Wright State University, used randomly amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) generated profiles of naturally occurring crayfish. They found that changes in the underlying genetic diversity of these populations were significantly correlated with the extent to which they have been exposed to anthropogenic stressors. They concluded that this rapid and relatively simple technique can be used to develop a sensitive means of directly assessing the impact of stressors upon ecosystems. These Wright State University researchers have also used the RAPD-PCR techniques on populations of snails, pill bugs, violets, spiders, earthworms, herring, and some benthic macroinvertebrates, finding relatively few obstacles in its use for different organisms. As noted above, other researchers have used DNA profiling techniques to identify sources of *E. coli* bacteria found in coastal waterways. It is possible that these techniques can be expanded to enable rapid detection of many different types of pathogens in receiving waters, and the most likely sources of these pathogens.

Other Tracer Methods for Identifying Sources of Water. Stable isotopes had been recommended as an efficient indicator of illicit connections to storm sewerage. A demonstration was conducted in Detroit as part of the Rouge River project to identify sources of dry weather flows in storm sewerage (Sangal, *et al.* 1996). Naturally occurring stable isotopes of oxygen and hydrogen can be used to identify waters originating from different geographical sources (especially along a north-south gradient). Ma and Spalding (1996) discuss this approach by using stable isotopes to investigate recharge of groundwaters by surface waters. During water vapor transport from equatorial source regions to higher latitudes, depletion of heavy isotopes occurs with rain. Deviation from a standard relationship between deuterium and 180 for a specific area indicates that the water has undergone additional evaporation. The ratio is also affected by seasonal changes. As discussed by Ma and Spalding (1996), the Platte River water is normally derived in part from snowmelt from the Rocky Mountains, while the groundwater in parts of Nebraska is mainly contributed from the Gulf air stream. The origins of these waters are sufficiently different and allow good measurements of the recharge rate of the surface water to the groundwater. In Detroit, Sangal, *et al.* (1996) used differences in origin between the domestic water supply, local surface waters, and the local groundwater to identify potential sanitary sewage contributions to the separate storm sewerage. Rieley, *eta/.* (1997) used stable isotopes of carbon in marine organisms to distinguish the primary source of carbon being consumed (sewage sludge vs. natural carbon sources) in two deep sea sewage sludge disposal areas.

Stable isotope analyses would not be able to distinguish between sanitary sewage, industrial discharges, washwaters, and domestic water, as they all have the same origin, nor would it be possible to distinguish sewage from local groundwaters if the domestic water supply was from the same local aquifer. This method works best for situations where the water supply is from a distant source and where separation of waters into separate flow components is not needed. It may be an excellent tool to study the effects of deep well injection of stormwater on deep aquifers having distant recharge sources (such as in the Phoenix area). Few laboratories can analyze for these stable isotopes, requiring shipping and a long wait for the analytical results. Sangal, *etal.* (1995) used Geochron Laboratories, in Cambridge, Massachusetts.

Dating of sediments using 137Cs was described by Davis, et *al.* (1997). Arsenic contaminated sediments in the Hylebos Waterway in Tacoma, WA, could have originated from numerous sources, including a pesticide manufacturing facility, a rock-wool plant, steel slags, powdered metal plant, shipbuilding facilities, marinas and arsenic boat paints, and the Tacoma Smelter. Dating the sediments, combined with knowing the history of potential discharges and conducting optical and electron microscopic studies of the sediments, was found to be a powerful tool to differentiate between the different metal sources to the sediments.

Conclusions

Recent tests examined several potential tracer parameters during a project characterizing stormwater that had collected in telecommunication manholes, funded by Tecordia (previously Bellcore), AT&T, and eight regional telephone companies throughout the country (Pitt and Clark 1999). Numerous conventional constituents, plus major ions, and toxicants were measured, along with candidate tracers to indicate sewage contamination of this water. Boron, caffeine, coprostanol, *E.* co//, enterococci, fluorescence (using specific wavelengths for detergents), and a simpler test for detergents were evaluated, along with the use of fluoride, ammonia, potassium, and obvious odors and color. About 700 water samples were evaluated for all of these parameters, with the exception of bacteria and boron (about 250 samples), and only infrequent samples were analyzed for fluorescence. Coprostanol was found in about 25% of the water samples (and in about 75% of the 350 sediment samples analyzed). Caffeine was found in very few samples, while elevated *E. coli* and enterococci (using IDEXX tests) were observed in about 10% of the samples. Strong sewage odors in water and sediment samples were also detected in about 10% of the samples. Detergents and fluoride (at >0.3 mg/L) were found in about 40% of the samples and are expected to have been contaminated with industrial activities (lubricants and cleansers) and not sewerage. Overall, about 10% of the samples were therefore expected to have been contaminated with sanitary sewage, about the same rate previously estimated for stormwater systems.

Additional laboratory tests, funded by the University of New Orleans and the EPA, were conducted using many sewage and laundry detergent samples and found that the boron test was a poor indicator of sewage, possibly due to changes in formulations in modern laundry detergents. Other laboratory tests found that fluorescence was an excellent indicator of sewage, especially when using specialized "detergent whitener" filter sets, but was not very repeatable. We also examined several UV absorbance wavelengths as sewage indicators and found excellent correlations with 228 nm, a wavelength having very little background absorbance in local spring waters, but with a strong response factor with increasing strengths of sewage. We recommend that our originally developed and tested protocol still be used as the most efficient routine indicator of sewage contamination of stormwater drainage systems, with the possible addition of specific *E. coli* and enterococci measurements and UV absorbance at 228 nm. The numerous exotic tests requiring specialized instrumentation and expertise reviewed in this paper do not appear to warrant their expense and long analytical turn-around times, except in specialized research situations.

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Elimination of Illicit Connections in Coastal New Hampshire Spurs Cooperation and Controversy

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Introduction

Discharging stormwater runoff into our waterways has long been an accepted practice. In theory, storm drainage pipes should only discharge during and after storm events unless the source is groundwater or surface water piped underground. Therefore, the dry weather discharge should be relatively free of contaminants. However, many communities across the country are finding out this is not always true. Some cities and towns are discovering illegal connections of residential and commercial sewer lines to storm water collection systems. Illicit connections have been identified by the New Hampshire Department of Environmental Services (DES) as the point source of high fecal coliform levels in the New Hampshire coastal basin (Jones, 1995). These illegal connections pose a health risk to those recreating in the coastal waters and have forced the closure of shellfish growing waters to harvesting.

Goals of the Coastal Investigations Programs

Determining the extent of dry weather contamination in storm drainage systems is the first step an investigator should take when researching stormwater pollution. Dry weather flows in storm drainage systems are often the result of groundwater infiltration, but can also result from inappropriate connections from commercial, industrial, or residential buildings. In 1996, the New Hampshire DES published the Coastal Basin Nonpoint Source Pollution Assessment and Abatement Plan (NHDES, 1996) that directed coastal investigations of each community's storm drainage system during dry weather. This decision to conduct dry weather investigations in the coast was made after 300 illicit connections were identified in the northern New Hampshire city of Berlin. State environmental officials were convinced that illicit connections were always present in storm drainage systems that were once considered a pollution threat only during wet weather.

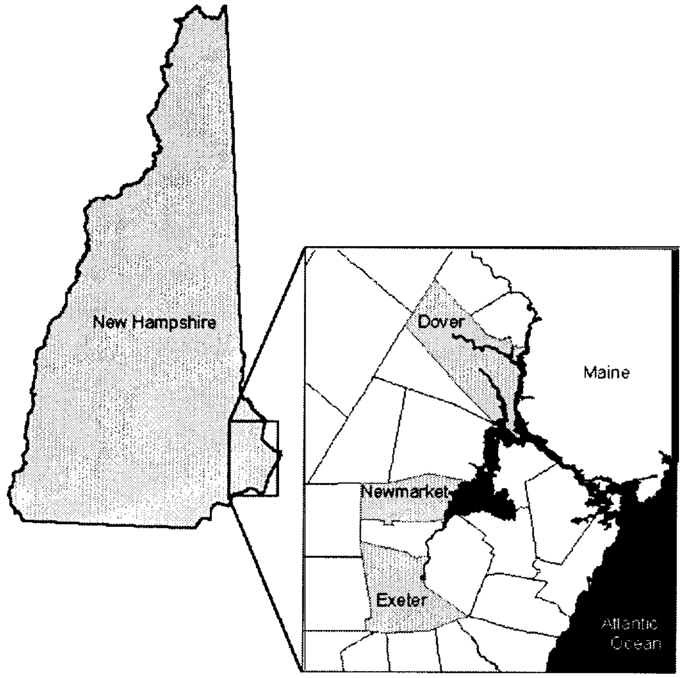
DES initiated a multi-year effort that focused on identifying and abating the sources of the bacterial violations found in the state's coastal waters with the goal of opening shellfish growing waters during dry weather (Landry, 1997). About the same time, the New Hampshire Estuaries Project (NHEP) began a three-year process of developing a comprehensive management plan aimed at restoring, protecting and enhancing the water quality and living resources of the state's estuaries. The major goal of the NHEP was to address the sources of pollution currently impacting the estuaries and prevent future problems through effective land use planning and shoreline protection of the coastal resources (NHEP, 1996). To accomplish this goal, part of the NHEP strategy was to locate and remediate the sources of the water quality violations, primarily bacterial violations, found in the estuaries and coastal waters (Landry, 1997). DES and NHEP combined resources and developed an investigation strategy with the overall goal of improving and protecting estuarine water quality.

Specific Program Objectives

The main objectives of the investigation strategy were to identify inappropriate connections in the storm drainage systems of urban, coastal communities and to eliminate the illicit connections through the available means, which include voluntary compliance and enforcement.

A Brief Look at Coastal New Hampshire

The eighteen miles of New Hampshire coastline do not begin to tell the story of the state's abundant marine resources. The relatively modest coastline is only a small part of the coastal basin. The estuarine resources include the Great Bay Estuary and seven associated tidal rivers, Hampton Harbor, and Rye Harbor. These waters are used by residents and many visitors for swimming, boat touring, shellfish harvesting, surfing, and angling. Forty-two communities



comprise the coastal basin watershed, with a population density just under 300 residents/mile^2 (Jones, In Review). The upper watershed is generally undeveloped and forested while the more urban centers are situated in the lower watershed as the rivers approach the coast.

Ten wastewater treatment facilities are situated on the tributaries of Great Bay and Hampton Harbor and two facilities discharge directly into the Atlantic Ocean. Coastal communities are working diligently to upgrade the wastewater treatment facilities and sewage collection systems. Inflow/infiltration problems and undersized pump stations plague the treatment facilities and have resulted in financial hardshipsforaffected municipalities. Shellfish growing waters have been temporarily closed after heavy rainstorms when bacteria levels rise due to sewage by-passes. Sewage is a well-recognized threat to the marine environment because it often contains harmful chemicals, disease-causing bacteria and viruses, dissolved material and solid matter. Pathogens can cause a variety of illnesses and humans are exposed to these organisms through contaminated water, shellfish, and fish (Sea Grant, 1999).

Investigating Illicit Connections

Recently, more and more watershed studies are investigating inappropriate discharges in storm drainage systems. This pollution source originates from an identifiable point and flows through the storm drainage system to the outfall pipe. For example, instead of connecting to the sewer system, a direct connection of sewer service discharges into the storm drainage system. Other inappropriate sources include floor drains and laundry pipes. These inappropriate connections are also referred to as illicit or illegal cross connections. The health threat and the potential to interfere with stormwater contamination assessments elevate illicit connections to priority status for watershed managers to investigate.

Pitt et al. (1993), in cooperation with the Center of Environmental Research Information, U.S. Environmental Protection Agency, published a user's guide for conducting investigations of illicit connections. Several of the methods suggested in this guide were implemented during the New Hampshire coastal investigations. Detailed surveys to determine the extent of contamination through specific water quality monitoring and careful observation of storm drainage outfalls are recommended for each type of land use in the watershed. Pitt recommends an initial phase of investigative protocol that includes the initial mapping and field surveys. The initial activities are followed by more detailed watershed surveys to locate and correct the sources of the contamination in the identified problem areas. After corrective action has been taken, repeated outfall field surveys are required to ensure that the outfalls remain uncontaminated.

Surveys of Storm Drainage Systems

Over the course of the investigations, several methods were used, ranging from the initial screening process of surveying storm drainage discharges to dye testing the indoor plumbing of suspected sources. Steps between the initial survey and the final determination of the source, included analyzing the discharge for water quality; visual and odor observations at outfalls, manholes, and catchbasins; smoke testing; and video inspection of the storm drainage and sewer systems.

Tidal rivers and coastal waters were divided into study sections by community. The urban, downtown centers of these communities were targeted based on the existence of the storm drainage infrastructure. The investigators compiled maps and as-built drawings of the storm drainage and sewer infrastructure. If the maps were inaccurate, insufficient, or unavailable, information on the storm drainage system was developed based on field investigations by the staff, typically with the assistance of public works employees.

Communities with maps based in a geographic information system (GIS) saved staff time and were generally more accurate than record drawings that are not updated regularly (Landry, 1997). Tuomari (1996) applied the Rouge Watershed Geographic Information System to the Wayne County Illicit Connections Detection Program and concluded that the new GIS strategy eliminated the need to use maps and graphics from disparate reports and sources, significantly reducing the time and effort once spent on research, field data acquisition, and interpretation.

Beginning in the summer of 1996, the coastal shorelines were surveyed at low tide, on foot or by canoe, depending on access, for potential pollution sources. All pipes, seeps, streams, and swales with flow were sampled for bacteria. In addition, temperature was measured and observations relating to the condition of the pipe (stained or structurally damaged), odor, evidence of untreated wastewater (toilet paper, etc.), turbidity, color, debris, estimated flow, and any other observations were noted. Dry pipes were rechecked on several occasions for intermittent flow. Evidence indicating the presence of wastewater and/or elevated bacteria levels prompted further investigation of these locations.

Upstream catchbasins and manholes associated with the outfall pipes that were identified in the screening process previously described, were surveyed for evidence of wastewater and sampled for bacteria. Smoke testing (using non-toxic smoke blown into catch basins) was then used to identify buildings connected to the storm drainage system by canvassing the neighborhood for vents emitting smoke. Final confirmation of an illicit connection from the buildings that emitted smoke was accomplished with dye testing of indoor plumbing and observing the storm drainage and sewer systems for the presence/absence of the dye.

Feeder streams were surveyed for outfall pipes with dry weather flow. Other potential bacteriological sources (e.g., pigeon roosting sites on bridges) were bracketed with water quality sampling stations. Where contaminated seeps and swales were suspected, the drainage area was surveyed for potential sources such as broken sewer mains.

Water Quality Results

Bacteria data (1997/98) from outfall pipes with confirmed cross connections ranged from 1,700 - >1,000,000 *E. coli* counts/l 00 ml during dry weather in Dover, New Hampshire. Many outfall pipes with cross connections had a gray biomat comprised of filamentous bacteria coating the inside of the pipe and, often, the rocks or sediment below. These biomats were used as a wastewater indicator based on the presence of these mats at more than 50% of the outfalls with confirmed cross connections.

Dr. Stephen Jones of the University of New Hampshire Jackson Estuarine Laboratory conducted a twelve-month study that examined the significance of all flow coming from urban storm drainage systems in the downtown Dover watershed of the Cocheco River (Jones, 1998). Jones found that storm drains were consistent sources of relatively high concentrations of bacterial indicators and pathogens at concentrations that exceeded state standards for recreational and shellfish-growing waters during both dry and wet weather.

Flow from a damaged stormwater outfall pipe was determined to have a geometric mean *E. coli* concentration of 1,047,199 cfu/100 ml and a dissolved inorganic nitrogen (DIN) concentration of 22.4 mg/l. The data were brought to the attention of DES and an investigation revealed a cross connection from a commercial building. Dr. Jones continued to monitor the quality of flow after the cross connection was eliminated and the results show a significant decline in both bacteria and DIN geometric means. The post-repair results were 93 *E. coli* cfu/100 ml and 7.2 DIN mg/l.

Although no public health problems were known to have occurred as a result of exposure to bacterial pathogens in the Cocheco River, the contamination may be a significant contribution to the fecal-borne bacteria that are presently the reason for closing the area's shellfish growing waters in New Hampshire and restricting harvests in Maine (Jones, 1998).

Remedial Actions

Once confirmed, illicit connections in coastal New Hampshire have been eliminated in different ways. The most desired course of action from the regulatory perspective is voluntary compliance and many fixes have been accomplished through this process. Economics and prioritization of the many demands on public works departments sometimes compel the state and federal environmental agencies to initiate regulatory action to eliminate raw wastewater discharges into surface waters. Lawsuits, although not common, have been filed against municipalities after cross connections were discovered.

Voluntary Compliance: Town of Exeter Case Study

In 1994, researchers at the UNH Jackson Estuarine Laboratory (Jones and Langan, 1995) reported elevated dry-weather bacterial levels collected in Norris Brook, a tributary to the Squamscott River in Exeter, New Hampshire. In 1996, DES collected bacteria samples at various locations on Norris Brook (NHDES, 1997) and found relatively low *E. coli* concentrations of <150 counts/l00 ml. In 1998, an Exeter official urged DES to investigate the watershed for contamination based on the 1994 data that showed a fecal coliform concentration of 600 counts/l 00 ml. In April of 1998, DES and a town official conducted a survey of the lower watershed and discovered a storm drainage outfall discharging a large volume of flow even though the weather had been dry. Upon closer inspection, toilet paper was observed in the outfall pipe and the immediate area.

The town public works department was notified of the survey results and, following reminders by DES, began investigations to determine the sources of untreated wastewater. Progress was slowed because several of the residences were rental properties which involved contacting the owner, who was in some cases from out-of-state, and gaining permission to access the building for dye testing. By November, the town reported that a few of the cross connections still remained. DES considered enforcement action and an administrative fine but did not take that action to maintain the spirit of cooperation. In January of 1999, the town reported that the owner of the last remaining property to be dye tested was not responding to requests for access. More prodding by DES followed and in February 1999, DES received notification that the cross connections were eliminated. A follow up inspection confirmed the absence of untreated wastewater in the storm drainage outfall.

A lesson learned from this experience is that a persistent, local advocate is often the key to maintaining attention on a local water quality problem. In addition, local advocates, whether a conservation commissioner, selectmen, or citizen, often have detailed knowledge of the complaint and the locale, which provides valuable and time-saving information to the state investigators.

Time and resource demands on local officials as well as state investigators can cause this process to be distressingly slow. Budgeting for 2-3 cross connection investigations and fixes per year is recommended at approximately $6,000 per fix, to help alleviate the unexpected financial burdens on urban communities when illicit connections are found.

Bacteria alone should not be the determining factor of the presence or absence of an illicit connection for a variety of reasons. Chlorine or other toxins in untreated wastewater may depress bacteria levels and bacteria lack conservative behavior, which deem it a poor indicator (Pitt, 1993). Investigators have found that a careful and thorough outfall survey is usually more informative than just collecting water samples.

Enforcement Action: City of Newmarket Case Study

Enforcement is another tool available to DES to achieve compliance. For example, setting timetables for compliance milestones in a legal document is a method that, while typically thought of as a burden to a community, may actually provide the impetus for action in a positive way. Public works departments of New Hampshire coastal communities are not equipped with large, discretionary budgets to address unplanned remediation of illicit connections. When faced with this dilemma, an enforcement action against the community provides public works departments with the validation to support a request for additional funding from the officials who approve the allocation of funds.

As the mill Town of Newmarket, New Hampshire, developed over the years, a small watercourse named Moonlight Brook was built over and culverted in the center of downtown. In 1996, DES investigated Moonlight Brook based on historic elevated bacteria levels. The DES investigation revealed dry weather *E. coli* concentrations as high as 41,600 counts/l 00ml in the brook. DES encouraged the town to initiate dye testing of the structures in the vicinity of Moonlight Brook but, at that time, the town was reluctant to allocate staff and funding for clean up efforts (NHDES, 1997).

An administrative order was issued by the US Environmental Protection Agency for various violations of permitted effluent limitations in October, 1997 and included a requirement that the town eliminate the raw sewage discharges from the storm sewer system (USEPA Docket No. 97-78). The order required a plan and schedule for eliminating any pollutants discharging during dry weather. The order also specified sampling of each active dry weather discharge that remained following elimination of the illicit connections to the system identified by the town's fieldwork.

In response to the order, the town hired an environmental consultant to address the problems at the wastewater treatment facility and the illicit connections. During the summer of 1997, the consultant and the town performed a dye study of the subdrainage area that the town suspected was the likely source of bacterial contamination identified at the discharge. The dye study resulted in the identification of a total of four untreated discharges to the storm drainage system from three properties. A subsequent video inspection of the sewer lines adjacent to these properties revealed that the sewer service connections from these properties might have been installed at the time the original sewer was constructed. The consultant then concluded that this would indicate the sources of sewage discharging to the storm drainage are broken sewer service connections rather than direct connections. The town stated that the remedial work would be completed by June 1998 (Plante, 1998).

Another storm discharge pipe servicing this area was separated in 1985 and 1986, at which time dye testing was performed to identify sanitary services that were connected to the sewer. The consultant determined that it would be unlikely that direct sanitary service connections to the storm drain were present in this area, however, broken service connections could result in sewage entering the storm drain culvert along Main Street. A dye study was planned for May 1998.

A total of 59 properties were included in the dye-testing program. Four of the properties were confirmed to be cross-connected to the storm drainage system. Two of the four were the result of direct connections of sewer laterals to the drainage system. The remaining two were a result of exfiltration from the sewer lateral through the ground to the drain line (Town of Newmarket, 1999). The town reports a 90% reduction in the *E. coli* counts following the elimination of the illicit discharges.

Legal Action: City of Dover Case Study

In the 1970's, the City of Dover, New Hampshire, constructed a new sewage collection system and treatment facility. In 1997, DES investigators began surveying the storm drainage outfalls for contamination. Around this same time, University of New Hampshire researcher Dr. Stephen Jones initiated a study in Dover to determine the significance of flow (both dry and wet weather) coming from urban storm drainage systems (Jones, 1998). Jones identified a source of bacterial contamination to be a cross connection later confirmed by DES and the City of Dover Public Works Department. The city fixed the illicit connection by connecting the sanitary service into the sewer main, at no charge to the building owner, while noting substantial flow from this service due to a hair salon in the building.

After learning about the existence of the cross connection, the building owners made an unsuccessful request to the city for an abatement of the sewer fees they had paid since 1981 and initiated legal proceedings. The city alleged that the case law mandated a decision in its favor and filed a motion for summary judgement (Strafford Superior Court, Order #98-C-207). In a responding order from the judge, the case law was said to illustrate that the Court had considered a variety of factors in related cases including (1) whether the new and old system were integral to one another, (2) whether the benefit provided to the plaintiff under the new and old systems was comparable, and (3) whether the property owner had access to the new system. The motion for summary judgment was denied because the Court found that these were issues for a jury and that summary judgment at that stage would be premature.

A trial date was set. One week before the trial was to occur, the two parties settled out of court. The terms of the settlement were confidential. If the property owners were successful in seeking a tax abatement and damages for unjust enrichment, implied contract, and negligent misrepresentation, as sought, the pollution investigations could have been in jeopardy of becoming ineffective. Such a precedent could have led to other similar suits and would effectively remove the incentive for municipalities to be proactive in fixing cross connections.

Conclusions

The Department of Environmental Services, in conjunction with the New Hampshire Estuaries Project, has systematically identified illicit connections in the urban communities of coastal New Hampshire. Applying both voluntary compliance and enforcement has resulted in the removal of cross connections to the storm drainage systems and a decrease in the contamination reaching the coastal surface waters. DES is currently monitoring the shellfish growing waters to determine the extent of water quality improvement resulting from the removal of illicit connections.

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Using Collaborative Problem-Solving to Protect North Carolina's Coastal Resources: The Experience of the White Oak River Advisory Board*

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Introduction

In North Carolina coastal estuarine systems, land use change has been implicated as a significant cause of water quality impairment (NC Department of Environment and Natural Resources, 1997; White, et al., 1998). Such development processes change surface hydrology, pollutant delivery, and, as a consequence, adjacent water quality. Decisions regarding placement, density, and type of development are controlled by policy implementation at the local level. Furthermore, while the degree of impact may vary with each location, it is the cumulative effects throughout a watershed that can be most damaging to water quality. Hence, there is a need to develop and enact policy locally, but on a multi-jurisdictional, watershed basis.

Increasingly, local communities and governments are showing interest in playing a role in developing and implementing solutions to water quality problems (NC Department of Environment and Natural Resources, 1997). However, logistical complications arise upon implementation of this concept. First, a mechanism for effectively involving local citizen stakeholders in the policymaking process may not exist and/or is difficult to establish (Danielson, 1998). Second, technical data needed to address local issues and concerns are often not readily available, or are in a form not easily understood. Third, programs for addressing water quality problems on a watershed-basis may not exist, suggesting a need to develop, coordinate, and deliver multi-jurisdictional education on water quality issues and policy alternatives. Through a project entitled Watershed Education for Communities *and* Local *Officials (WECO)*, the North Carolina Cooperative Extension Service has worked with a number of state and federal agencies, along with citizens and local governments within a coastal watershed to address these needs.

The goal of this project is to improve water quality in all of the White Oak River Watershed through involvement and education of citizens and government officials who live and work in the watershed. The project's main thrusts are : 1) the delivery of technical information and educational material on water quality, management strategies, and policy options that support watershed-based planning; 2) the empowerment of local citizens by facilitating collaborative partnerships between communities, local officials, and state agencies within the watershed; and 3) the facilitation of the development

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of local stakeholder - driven policy recommendations for the entire watershed. This paper discusses the application of these concepts to an issue of critical importance to local citizens.

Background

The White Oak River watershed is one of four rivers in the White Oak River Basin (Figure 1). It is 48 miles long and encompasses 320 mi^2 . The watershed begins in freshwater creeks and swamps of Jones County, NC, and contains portions of three other counties--Craven, Onslow, and Carteret. Along its route to Bogue Sound and the Atlantic Ocean, the river traverses between 30 ft. banks, which are relics of ancient dune ridges. This river is home to five threatened or endangered organisms, including alligators; loggerhead, green, and leatherback turtles, and the Croatan crayfish. The river and its estuarine waters have extensive primary nursery waters and provide habitat for several anadromous species--herring, shad, striped bass, and sturgeon. The majority of the river is classified as SA, or saltwater suitable for commercial shellfish harvesting.

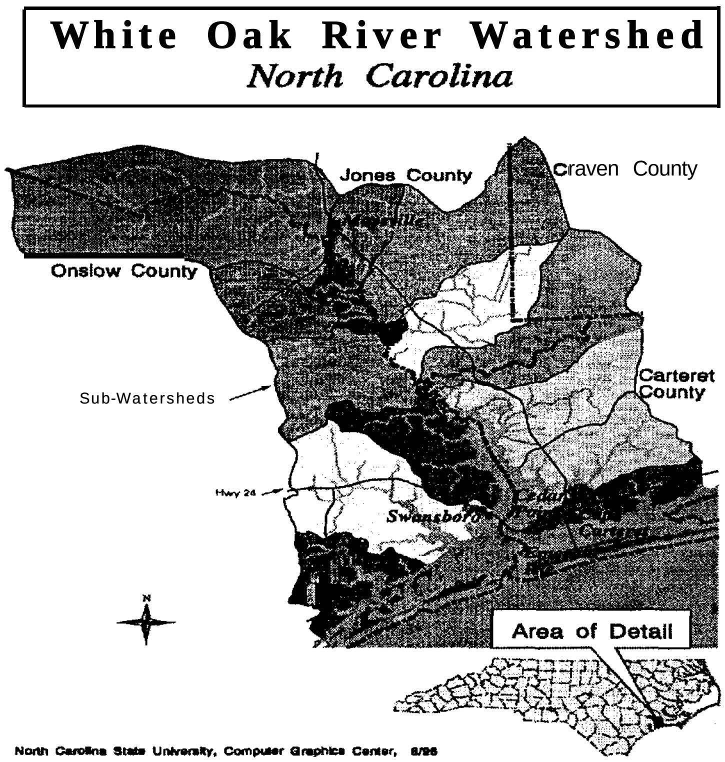

Figure 1. General map of White Oak River Watershed in North Carolina.

The White Oak River watershed has six major land cover/land use classes with wetlands encompassing the largest single type at 52% of the total. Forests are the second largest land cover type constituting the majority of the headwaters in the Croatan National and Hoffman State Forests (22%). A very small portion of the watershed is urban (2%) and agricultural (11%) (NC Department of Environment and Natural Resources, 1997).

Despite the low level of urbanization, the North Carolina Division of Water Quality's basinwide management plan notes an increase in shellfish closures in the river (North Carolina Division of Environmental and Natural Resources, 1997). At state-sponsored public meetings, over 100 citizens expressed concern and called for more public education on water quality.

Recognizing the interest of their constituencies in water quality education, local NC Cooperative Extension Service leaders assembled a project team involving members from the North Carolina Division of Water Quality, North Carolina Division of Coastal Management, North Carolina Division of Environmental Health - Shellfish Sanitation Branch, North Carolina Cooperative Extension, and 25 citizens who comprise the stakeholder-based Advisory Board for the White Oak River Watershed. This group includes crop farmers, livestock farmers, fisherpersons, developers, foresters, tourism directors, teachers, scientists, and local government officials from the watershed (see Table 1). The citizen advisory board is the decision-making entity. The government agency representatives and Cooperative Extension personnel function as support staff to the Board. Support staff provide resources, perform research and reviews, make reports, serve as technical advisors, and provide formal facilitation and consensus-building services.

The White Oak Advisory Board's Primary Issue of Concern

The Board began meeting in August of 1996. Their first task was to prioritize water quality issues upon which to focus their efforts, Board members expressed concern that past bridge and road construction across the mouth of the river had contributed to a decline in water quality. Furthermore, this road, Highway 24, was slated for expansion, and they were concerned that this would exacerbate the problems. The Board acknowledged the need for expansion of the road, but recognized a unique opportunity to mitigate its impact if they could move quickly to work with the North Carolina Department of Transportation (NC-DOT)

At the time that the Board was convened and identified the highway and its expansion as an issue, NC-DOT was in the process of conducting an Environmental Assessment of the project and were anticipating a Finding of No Significant Impact. During a meeting between the Extension Project Team and NC-DOT, DOT representatives were made aware of the Board's concerns and expressed an interest in working with the Board to address those concerns. However, timing was an issue because in several months, NC-DOT was planning right of way acquisition to begin the expansion project. Because of the urgency of the matter, the Board resolved to meet twice monthly and work to develop their comments and recommendations.

Technical Information Gathered by the Board

In response to the Board's inquiry, the Project Team reviewed, summarized, and presented scientificstudies that had been conducted on the river that related to sedimentation and flow patterns in the river and the possible effects of highway construction over the mouth of the river. Results from the following four studies were especially useful in understanding the science behind this policy issue.

Table 1. White Oak River Watershed Advisory Board – Stakeholder Composition.

Stakeholder Groups	Carteret	Jones	Onslow	At Large	Total
Fishing, Commercial	· · · ·				4
Fishing, Recreational			·		1
Real Estate or Development	·				1
Environment/ Conservation	·				1
Farming, Crop	·	·			2
Farming, Livestock			·		1
Forestry, Private			·		1
Business & Industry	·	· ·			3
Local Government	· ·	·			3
Academia/ Public Schools	· ·		· ·		4
Travel & Tourism					
NC Shellfish Sanitation				·	1
Soil & Water Cons.		·			1
Public Forestry				· ·	2
Totals	12	5	5	3	25

One study (Martens and Goldhaber, 1978) determined that the metabolic pathways by which bacteria degrades organic matter in the sediments differ depending on whether the overlying aquatic environment is salty or fresh. Chemistry analyses done on soil cores taken at various locations in the river found framboidal pyrite at upstream samples, which indicated that saltwater wedges had previously penetrated further upstream than current patterns in soil chemistry showed. These results provided evidence to the Board that saltwater flows in the river had changed over time.

Adams, Benniger, Hosier, Overton, and Reed (1982) studied water circulation and sedimentation patterns in the White Oak Estuary and found that sedimentation in the estuary varies from 0.3 cm/yr to 5 cm/yr. approximating the annual rate of submergence along the Atlantic coast. Their study confirmed for the Board that the system is a flood tide dominated system with sediment transport primarily occurring during storms with strong on-shore winds. The study also noted that the construction of the Intracoastal Waterway (ICWW) in 1930-32 in conjunction with the construction of Highway 24 in 1933 altered channel flow from one channel (adjacent to Huggins Island) to another (adjacent to the mainland near Highway 24). Spoil deposition from dredging operations may also be responsible for decreased channel flow in the west channel of the Inlet. The authors noted no evidence of a declining fishery based on the fact that it was comparable to other fisheries in the area and in line with historical production rates for the estuary. This study also quantified the extent of fill and alteration to the estuary caused by the original construction of the ICWW and the road in 1932 and 1933, respectively. Historical maps, when compared to current data, showed that two inlets were closed and that more than 80% of the river was obstructed by these projects.

Benniger and Martens (1983) investigated the age and the sources of organic matter in the estuary. This study characterized the organic matter degradation rates, which is important in understanding the estuary's capability to process organic inputs. The researchers determined that the upstream organic matter inputs were primarily terrestrial and the downstream organic inputs were primarily marine. However, they found that microbial processes acted preferentially to remove recently produced organic matter. This implies that recently produced or partially treated organic matter could substantially increase sediment oxygen demand and the rate of nutrient regeneration. This would increase the vulnerability of the estuaries to anoxia and algal blooms.

Kelley, Martens, and Chanton (1990), by collecting and analyzing sediment cores, characterized the relative remineralization rates of sedimentary carbon for the fresh and saltwater environments in the river. They found that the upstream environment, which is dominated by terrestrial inputs and the process of methane reduction, remineralized at a rate three times faster than the downstream site, which is dominated by marine inputs and uses sulfate reduction as the energy pathway for organic matter remineralization. As indicated in the previously described paper by Martens and Goldhaber (1978), saltwater circulation patterns, as well as freshwater inputs, appear to have changed such that the estuarine ecology has shifted towards a more freshwater system. Since freshwater facilitates rapid remineralization of organic carbons, this, over time, can reduce the river's buffering capacity and result in nutrient enrichment.

Initial Conclusions of Board

Based on these and other related studies, the Board concluded the following:

- Salt wedges that used to extend upstream have not occurred in recent history.
- Organic inputs upstream are from terrestrial sources and downstream are from marine sources.
- Salinity regimes in the river are highly variable seasonally and spatially.
- Salinity helps buffer the river from nutrient inputs.
- Sedimentation at the mouth of the estuary was considered normal for coastal estuary systems.
- There was no evidence to support a perceived decline in the fishery.
- Increased fresh water inputs from the expanded impervious surface area related to the highway expansion may have a negative impact.

- Higher salinity reduces concentrations of fecal coliform bacteria.

- Ditching and other means of moving water faster off the land causes problems with increased freshwater to the river as well as increased bacterial contamination in shellfish beds.

- There is a significant shellfish resource at the mouth of the river that has historically remained open.

Next, the Advisory Board convened a panel of specialists to discuss this information and potential mitigation strategies. The panel participants included:

- Dr. Larry K. Benninger, Geologist, University of North Carolina at Chapel Hill (UNC-CH);

- Archie Hankins, Biologist, NC-DOT;

- Tom Jarrett, Hydraulic Modeling, United States Army Corps of Engineers (USCOE);

- Dr. Chris Martens, Marine Sciences, UNC-CH;

- Dr. Paul Hosier, Biologist, UNC-CH;

- Dr. Rick Leuttich, Sedimentary Geologist, UNC-CH; and

- Howard Varnam, Hydrologist, USCOE.

The panel reviewed the scientific information presented to the Board, and they agreed that there has been an impact on the circulation and flushing of the White Oak River since the construction of the causeway and the ICWW, but quantification of those effects would require intensive modeling that would take a minimum of 1.5 to 2 years. The panel felt that any action to increase circulation and salt water inputs to the river would have an overall positive effect on water quality. However, the best manner in which to accomplish those goals and the particular effects on fisheries, sedimentation, or other water resource values would be difficult without modeling studies. The panel concluded that due to changes in land use, hydrology in the watershed had been altered. As a result, runoff volume during storm flows has increased. This increases pollutant loading and increases erosion processes during storms. The panel noted that a reduction in freshwater runoff would not have any significant effect on the diversity and density of species, but on their distribution. This would have little effect on flora and fauna in the river, but might improve water quality. The panel also noted that the most effective strategy for protecting water quality is to involve all of the communities impacting the system and to implement overall land use planning in the watershed. It was suggested that the group needed to define their water quality goals and how they want to manage the river and watershed to achieve those goals. Individual actions for localized effects would require some additional modeling and research to determine the best options.

The panel concluded with a list of mitigation recommendations listed below:

- Pursue a study of the river to determine what, if any, actions should be taken to improve circulation up and downstream of the highway.

- Examine options to manage stormwater in new and existing developments.

- Pursue the maintenance of buffers along creeks and streams.

- Pursue stricter enforcement of sediment and erosion control at construction sites.

- Endorse, encourage, and facilitate the use of BMPs in forests and farms.

- Work to develop a mechanism for watershed - based or coordinated land-use planning to address all of the suggestions.

- Explore alternative waste management strategies for both single users and municipalities to reduce nutrients.

The Board's Recommendations

Over the next several meetings, and as a consequence of these findings, the Board recommended the following actions;

1. To reduce freshwater inputs to the estuary and possible negative impacts of highway runoff on water quality, the Advisory Board recommended storm water runoff from bridge and highway expansion not be discharged into the river and that the Department of Transportation (DOT) explore options to eliminate discharge into the waterways. At a minimum, discharge from Highway 24 should be directed south (downstream) of the causeway to prevent impacts to shellfish. In addition, it was recommended that amelioration of the velocity, volume, and quality of that runoff be implemented, if feasible.

2. Historic maps showed that, prior to the 1930's, the mouth of the White Oak River was open and unrestricted, allowing free tidal flow. In 1932 and 1933, Department of Transportation and US Army Corps of Engineers (ACOE) projects closed approximately 80% of the mouth of the river and altered physical processes. The Advisory Board recommended that to restore salinity regimes, increase tidal circulation, and reduce sedimentation, DOT take actions to reopen the mouth of the river to the maximum extent possible. One option would be the creation of a north-south channel connecting the estuary with the sound near the current location of the Flying Bridge Restaurant on the Carteret County side of the river spanned by a bridge or connected by a culvert. Additionally, the Board recommended that DOT and ACOE access ACOE ecological restoration funds and collaborate with each other to mitigate the impacts of this expansion and past actions.

3. Since efforts to open the channel would not remain effective unless the State of North Carolina initiates an ongoing maintenance program, the Advisory Board recommended that a long-term maintenance program supporting improved circulation, reduced sedimentation, and restored salinity regimes be developed and implemented by responsible agencies.

These recommendations were presented to and adopted by commissioners for Carteret and Jones Counties in May and June of 1997. In addition, the White Oak River Watershed Advisory Commission of Onslow County (a group appointed by the Onslow County Board of Commissioners to address water quality issues in Onslow County) endorsed the recommendations of the Board at their May of 1997, meeting. This collaborative, consistent, watershed-based policy statement became part of the public record for the NC-DOT hearings in May of 1997, and a preliminary draft was included in the NC Division of Water Quality's Basinwide Water Quality Management Plan for the White Oak River Basin (North Carolina Division of Environmental and Natural Resources, 1997).

Response to the Recommendations of the Board

At a joint meeting that included representatives of the NC-DOT, the White Oak River Advisory Board, the Extension Project Team, and USCOE, the DOT agreed to support the Board's recommendations and revise their stormwater plans to direct runoff away from the shellfish resource in the river.

Blueprints for construction were redrawn reflecting the following features. In the vicinity of the bridges carrying Highway 24 over the White Oak River at Swansboro, NC-DOT agreed, to the extent possible, to direct the stormwater runoff from the roadway to the Bogue Sound side of Highway 24 and away from the river. In Swansboro (west of the island causeway), the existing stormwater collection system (which has outfalls on both the river and sound side of Highway 24) will continue to be used for the runoff following roadway expansion, thus preventing the need for additional outfalls in the river.

From the island causeway eastward for approximately 2.5 miles, the stormwater runoff from the highway will be collected and piped to outfalls on the sound side of Highway 24. Also, NC-DOT has designed special channelization islands for commercial driveways to accommodate some of the stormwater runoff from the highway and bridges. These water quality islands are depressed inside the curb to allow the first inch of highway runoff to pond within these islands and filter through the grassed areas located there. The filtered runoff from these islands is then collected and piped to outfalls on the sound side of Highway 24.

In addition to the stormwater design changes, it was agreed that DOT would cooperate with other state and federal agencies in any efforts to improve circulation and tidal flushing. Currently, the Board is continuing to work on adding a section to the Congressional *Water Resources* Development *Act* that would authorize the USCOE to conduct the study necessary to determine what, if any, actions could be taken to improve flushing in the river.

Conclusions

Local stakeholder-based citizen groups can impact policies that affect their environment. Support for gathering, summarizing, and delivering technical information to local citizens and governments is an important aspect of the success of these processes. Knowing who to approach for answers to specific questions, and where to look for scientific information is an important function of the group's technical support. In addition, translating the information gathered into digestible and usable material is also critical.

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Community Responses to Stormwater Pollution: Case Study Findings with Examples from the Midwest

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Stormwater runoff threatens the nation's waterways and public health, and costs Americans hundreds of millions of dollars each year. Concerns about urban runoff and interest in proposed new federal stormwater regulations prompted the Natural Resources Defense Council (NRDC) to document existing, effective stormwater strategies. Our report aims to encourage municipal action and empower communities to address this critical issue. More than 150 case studies from across the nation were compiled and evaluated to highlight effective pollution prevention, administrative, and financing strategies for addressing stormwater runoff. The case studies show, on a practical level, that stormwater management can be environmentally effective, economically advantageous, and politicallyfeasible. The reportalsoforms the foundation of a comprehensive outreach effort. Together, they help guide communities as they implement or improve stormwater management programs by providing detailed examples of proven tools and approaches used to prevent stormwater pollution. Collectively, the case studies offer an outline for further successful stormwater management strategies. Elements critical to the effectiveness of these programs include: a pollution prevention emphasis with structural treatment measures when needed; a focus on preserving natural features and processes; programs that inform and involve the public; a framework that creates and maintains accountability; a dedicated and equitable funding source to ensure long-term viability; strong leadership; and effective administration. These broad themes translate into a set of nine local actions for addressing the technical, social, and political issues associated with stormwater runoff. The case studies show that following these actions will help communities form a sound stormwater policy.

Key Terms: urban stormwater runoff, impervious surfaces, pollution prevention, best management practices, diffuse pollution, accountability.

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Introduction

Currently, there is substantial concern about the impacts of urban and suburban runoff. Pollution from diffuse sources, including urban stormwater, is the leading source of contamination in the nation's waters (U.S. Environmental Protection Agency, 1997a). Stormwater runoff pollution is a particularly important issue since most of the population of the United States lives in urban and coastal areas. Water resources in urban and coastal areas are highly vulnerable to and are often severely degraded by stormwater runoff. Specifically, urban and suburban runoff is the second most prevalent source of water quality impairment in the nation's estuaries after industrial discharges (U.S. Environmental Protection Agency, 1998b).

Economic impacts are an important aspect of this concern. Even a partial accounting shows that hundreds of millions of dollars are lost each year through added government expenditures, illness, or loss in economic output due to urban runoff pollution and damages (U.S. Environmental Protection Agency, 1998a). The ecological damage is also severe and is at least as significant. In particular, uncontrolled urban runoff contributes to hydrologic and habitat modification, two important sources of river impairment identified by the U.S. Environmental Protection Agency (EPA).

The polluted stormwater runoff problem has two main components: the increased volume and rate of runoff from impervious surfaces and the concentration of pollutants in the runoff. Both components are closely related to development in urban and urbanizing areas (Booth and Reinelt, 1993; Schueler, 1994; U.S. Environmental Protection Agency, 1997b). When impervious cover (roads, highways, parking lots, and roof tops) reaches between 10 and 20 percent of the area of a watershed, ecological stress becomes clearly apparent (Klein, 1979; Booth and Reinelt, 1993; Schueler, 1994). Everyday activities can deposit on these surfaces a coating of various harmful materials. When it rains or when snows melts, many of these pollutants are washed into receiving waters, often without any treatment.

The deposition of pollutants and the increased velocity and volume of runoff together cause dramatic changes in hydrology and water quality (Klein, 1979; Jones and Clark, 1987; Booth, 1990; Galli, 1990; U.S. Environmental Protection Agency, 1997b). These changes affect ecosystem functions, biological diversity, public health, recreation, economic activity, and general community well-being (Bannerman *ef al.,* 1993; Novotny and Olem, 1994; Haile *et al.,* 1996; Carpenter *et al.,* 1998). Urban stormwater is not alone in polluting the nation's waters. Industrial and agricultural runoff are often equal or greater contributors. But the environmental, aesthetic, and public health impacts of diffuse pollution will not be eliminated until urban stormwater pollution is controlled.

While urban and suburban runoff continues to be a critical issue, there is substantial evidence that the problems are not intractable. Increasingly, communities are recognizing the causes and consequences of uncontrolled urban runoff and taking action to control and prevent runoff pollution, often without any mandate. These innovative communities are realizing the environmental, economic, and social benefits of preventing stormwater pollution. However, neither the extent of these efforts nor the specific actions being taken have been well documented.

There is also a growing interest in proposed new federal stormwater regulations. Comprehensive stormwater regulation is required under Section 402(p) of the Clean Water Act. Since 1992, cities with populations over 100,000, certain industries, and construction sites over 5 acres have been required to develop and implement stormwater plans under Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations (U.S. Environmental Protection Agency, 1990). In October 1999, EPA is expected to promulgate a new rule requiring municipalities with populations fewer than 100,000 people located in "urbanized areas" (where population density is greater than 1,000 persons per square mile) to develop stormwater plans. Under what is known as the "Phase II" rule, the EPA and states will develop "tool boxes" from which the smaller local governments can choose particular stormwater strategies to develop their stormwater plans (U.S. Environmental Protection Agency, 1998a).

To address all of these issues and concerns, the authors developed a study to examine, document, and disseminate information on environmentally effective and economically advantageous stormwater pollution prevention strategies. The study resulted in a report, *Stormwater Strategies: Community Responses fo Runoff Pollution*, that highlights some of the most effective existing stormwater strategies from around the country (Lehner et *al.,* 1999). The report provides substantial evidence that such programs exist and highlights a variety of innovative strategies actually being used. The report also aims to provide guidance to communities addressing stormwater issues, encourage municipal action, and help empower communities to be involved in this critical issue. This paper summarizes the study and presents its primary findings and recommendations.

Study Design and Approach

The study was exploratory in nature, with the intent of presenting information on existing effective stormwater management programs. To achieve this goal, we collected examples of environmentally beneficial and cost-effective stormwater programs from across the country. We compiled this information into the case-study-based report described above. This information and report have become the basis for a comprehensive outreach effort.

The first step was to gather information on programs and projects by examining existing programs (several begun under Phase I as well as many that started earlier), reviewing literature, contacting regional and local stormwater management experts and researchers, and interviewing representatives from stormwater management or other local government agencies. We gathered information on over 250 programs. The information was then examined in detail and narrowed down to a set of case studies that demonstrated elements of success. Three fundamental criteria for selection were used: environmental gains, economicadvantages, and community benefits. Environmental gains included biological, hydrological, or chemical improvements resulting from stormwater management. Economic advantages included cost savings to the municipality or developers, or increases in property values related to the pollution prevention measure. Community benefits included aesthetic or recreational enhancement, administrative or institutional successes, or community relations improvements.

Seventy-seven programs and projects were selected as case studies for the final report. Another 88 programs were annotated to provide additional programs/locations not fully evaluated for the report. The case studies represent communities of all sizes, types, and regions throughout the United States. To help ensure accuracy, local experts or people familiar with the program, called "groundtruthers," were contacted to review the case studies and add information from their own knowledge and experience.

The case studies were first organized geographically by dividing the United States into six regions based in part on general rainfall patterns. Within each of the regions, case studies were then further subdivided into five categories of stormwater management measures including, (1) addressing stormwater in new development and redevelopment, (2) promoting public education and participation, (3) controlling construction site runoff, (4) detecting and eliminating improper or illegal connections and discharges, (5) and implementing pollution prevention for municipal operations. These categories roughly parallel those measures that large municipalities address under existing Federal regulations (40 CFR parts 122.26 and 123.25) and small municipalities will address under pending Federal regulations (U.S. Environmental Protection Agency, 1998a).

Case Study Findings

Through reporting over 150 examples of actual programs, the full report provides substantial evidence that stormwater pollution can be reduced or prevented with proper planning and implementation in growing or re-developing areas. The examples presented in the report also demonstrate that if some communities can measurably and cost-effectively reduce stormwater pollution, so can other communities and states (Lehner, et al., 1999).

The Five Categories of Stormwater Management Measures

Individually, the case studies provide detailed examples of substantial water quality improvement, effective or innovative stormwater control strategies to protect the natural environment, significant cost-savings, and important ancillary benefits to the community. The programs and strategies highlighted come from communities of all sizes, types, and regions. They include efforts by municipal agencies, developers, and community groups. In many cases, several of these groups worked together to create win-win outcomes. The case studies highlight a variety of strategies for addressing the five categories of stormwater management measures previously enumerated, and are described in more detail as follows.

Addressing Sformwaferin New *Development and Redevelopment.* By far the most important category of stormwater strategies focuses on land use and development. It encompasses a wide range of measures including regional or watershed planning, buffers and open space preservation, infill development, conservation design, and the use of site-specific structural and nonstructural treatment measures. One of the best strategies a municipality or developer can employ is to minimize the aggregate amount of new impervious surfaces. For example, developers of the Prairie Crossing project in Grayslake, Illinois, prevented runoff pollution and saved money by using conservation design strategies. The developers first reduced impervious cover by clustering 317 residences on only 132 acres of the site, which left 80 percent as open space. They then designed the developed area around a natural drainage system consisting of vegetated swales, restored prairie, and wetlands. Modeling indicates that this stormwater treatment drain system will remove approximately 85% of nutrients, metals, and suspended sediments and reduce peak flows by 68%. Eliminating curbs and gutters resulted in savings of $1.6 to $2.7 million. The development is also very appealing to homebuyers, with sales comparable to or better than conventional developments in the area (see Lehner *et al., 1999,* p. 224).

Promoting Public Education and Participation. Individuals play a key role in reducing stormwater impacts both in their own day-to-day activities and in showing support for municipal programs and ordinances. The most successful highlighted programs accomplished three goals: they educated the public about the nature of the problem, they informed the people about what they can do to solve the problem, and they involved citizens in hands-on activities to achieve pollutant reduction or restoration targets. One example of this success is in Minneapolis, Minnesota, where a decline in water quality motivated the Lake Harriet Watershed Awareness Project. Monitoring revealed that lawn-care chemicals were a significant contributor to the problem, which suggested focused education efforts. In turn, the project developed two approaches: a volunteer master gardener program and the distribution of educational materials. Evaluation showed that 67% of watershed residents reported using the information presented and 30% reported a change in behavior. As a result, concentrations of lawn-care pesticides have dropped by 50% or more since the program began (see Lehner *et al.,* 1999, p. 231).

Controlling Construction Site Runoff. The case studies demonstrate that effective construction site pollution prevention is politically and economically feasible and can dramatically reduce pollution. The most effective programs rest on four cornerstones laid in pairs: enforcement and education; erosion prevention and sediment control. However, the first and over-arching necessity is a clear set of requirements. For example, Herzog *et a/.* (1998) found that in Geauga County, Ohio, and St. Joseph County, Indiana, aggressive, widespread seeding and mulching reduced construction site erosion by up to 86% and reduced phosphorus loadings by 80%. These measures can also benefit developers financially. They found that homebuyers perceive these “green” lots to be worth $750 more than comparable “brown” lots (see Lehner *et a/.,* 1999, p. 236). While existing programs employ a wide variety of erosion and sediment control practices, virtually all successful strategies require proper planning and phasing of construction activities to minimize land disturbance.

Defecting and Eliminafing Improper or Illegal Connections and Discharges. Local governments have found that identifying and eliminating illicit connections and discharges is a remarkably simple and cost-effective way to address some of the worst stormwater pollution. The case studies show that two factors are critical to success of this element of stormwater programs: finding illicit connections and discharges, and enforcement. In Washtenaw County, Michigan, the Huron River Pollution Abatement project resulted in a 75% reduction in the river’s fecal coliform levels in just 4 years. The project focused on eliminating existing illicit connections and preventing future incidents through chemical storage surveys, industrial inspections, water-quality monitoring, public education, and complaint and spill response. Over a six-year period, the program dye-tested more than 3,800 facilities, after which 328 of the 450 illicit connections found were removed (see Lehner *et al.,* 1999, p. 239).

Implementing Pollution Prevention for Municipal Operations. A wide range of municipal operations can affect stormwater quantity and quality. The case studies reveal that some local governments have been able to manage their municipal operations to reduce stormwater pollution. The municipalities highlighted have done so in a variety of ways including reducing the use of harmful chemicals in the maintenance of municipal properties and vehicles, improving the maintenance and cleaning of roads and stormwater infrastructure, and training staff in pollution prevention practices. Several municipalities have taken these steps at their golf courses. For example, the Village Links Golf Course in Glen Ellyn, Illinois, is preventing runoff pollution by incorporating integrated pest management, water conservation, stormwater detention, native planting, recycling, and public outreach into its day-to-day management. The golf course relies on both mechanical and biological pest controls and has significantly increased natural areas. The course collects runoff from nearby streets and neighborhoods in its system of ponds and spillways. These ponds provide approximately 60% of the course's irrigation water, and the course itself passively treats and filters all excess runoff from irrigation (see Lehner *et a/.,* 1999, p. 243).

Themes Common to Success Stories

Collectively, over 150 case studies present a clear model for success. Evaluation of the case studies revealed several common elements among the highlighted programs. We distilled those elements into the seven broad themes listed below to help guide communities as they develop or improve stormwater programs. Since they are based on actual programs, these themes form a solid foundation for successful programs.

Preventing pollution is high/y effective and saves money. Pollution prevention measures dramatically and cost-effectively reduce the quantity and concentration of pollutants "winding up" in stormwater. Common pollution prevention measures include reducing or eliminating the use of harmful products, preventing erosion, reducing the amount of pavement in new developments, and changing maintenance practices. In highly urbanized areas, however, such measures may be difficult. In such cases, several communities have found treatment of runoff with structural measures or retrofitting existing structures to be effective alternatives.

Preserving and utilizing natural features andprocesses have many benefits. Many communities and developers have found strategies that rely on natural processes to be highly effective and economically advantageous. Undeveloped landscapes absorb large quantities of rainfall and snowmelt and vegetation helps to filter out pollutants from stormwater. Buffer zones, conservation-designed development, sensitive area protection, or encouragement of infill development all enhance natural processes.

Educafingandinforming the general public and municipal staff improves program effectiveness. Providing information and training to the general public and local businesses is a key component to many of the highlighted programs. Since many sources of stormwater pollution are derived from individual activities such as driving and maintaining homes, educating the public goes a long way to reducing stormwater pollution. Several communities involve the public in civic activities, such as monitoring water quality or stenciling storm drains, which not only provide educational opportunities but also save the municipality money.

Strong incentives, routine moniforing, and consisfenf enforcement establish accountability. Enforcement, or more broadly accountability, is a key element to improving water quality. All actors need a clear statement of performance goals, and they need to be held accountable by others for accomplishing these goals. We found that programs with high accountability were the most effective, often achieving pollutant reductions of 50% or greater.

Financial stability helps ensure effective programs. Effective stormwater programs are financially viable and affordable. Dedicated funding sources, such as stormwater utilities or environmental fees are equitable ways to build stability into stormwater programs. Stability and equity are also important in gaining public support. Nearly 200 communities across the nation are already realizing the benefits of implementing stormwater utilities as dedicated and equitable funding sources.

Strong leadership is often a catalyst for success. Success, at least initially, often requires an individual to champion the project and make it happen.

Effective administration is critical. Regardless of which strategies a community chooses, those programs with clear goals and objectives are the most successful. Such clarity enhances accountability, responsibility, and trust. Furthermore, an established and understood institutional framework often improves administration by fostering collaboration among different parts and levels of government, neighboring communities, and local citizens. Effective administration allows implementation of broad-based, multi-faceted programs, which are often the most effective at controlling the diffuse problem of stormwater pollution.

Authors' Recommendations for Local Action

To further guide communities addressing stormwater runoff issues, we translated the broad themes presented above into an action plan based on nine key recommendations. These actions roughly parallel the broad themes presented above. The case studies demonstrated that following the nine local actions outlined below will help build a strong framework for effective, efficient, and successful stormwater management over the long term.

1) *P/an in advance and set clear goals.* Carefully plan programs, as opposed to simply reacting to provided opportunities, crises, or transient pressures. Planning allows development of more effective and cost-effective actions. An essential outcome of planning is addressing the issues and concerns of all stakeholders involved.

2) *Encourage and facilitate broadparficipation.* Program planning, development, and implementation should involve multiple levels of government, key members of the community, and professionals from a variety of related disciplines. A key to success is the public's understanding of the issue, how it relates to them, and what they can do about it.

3) *Promote public education opportunities.* Implement broad-based programs that reach a range of audiences and solicit different levels of public involvement. Remain committed to the education program and take advantage of existing community organizations to enhance participation.

4) *Work to prevent pollution first; rely on structural treatment on/y when necessary.* Focus on prevention-based approaches, through regional and watershed planning, local zoning ordinances, preservation of natural areas, stormwater-sensitive site design, and erosion prevention as these are significantly more effective than treatment of polluted runoff.

5) *Establish and maintain accountability.* Essential components of this process are setting clear standards, creating strong incentives and disincentives, conducting routine monitoring and inspections, keeping the public informed, promoting public availability of stormwater plans and permits, and consistently enforcing laws and regulations. Strong enforcement is often key to significant water quality improvements.

6) *Secure financial resources.* Consider establishing a dedicated funding source such as a stormwater utility. Combine with it budget-saving measures such as creative staffing, public-public and public-private collaboration, and building off existing programs.

7) *Tailor strategies to the region and setting.* Recognizing that every case will be different, consider strategies that are particularly tailored to the region, the specific audience, and the problem.

8) *Evaluate and allow for evolution ofprograms.* Set clear goals and priorities, and allow programs to develop over time. Establish clear ways to check and see that goals and objectives are being met. This opens opportunities for improvements and helps ensure long-term success.

9) *Recognize the importance of associated community benefits.* Stormwater pollution prevention measures usually offer ancillary quality-of-life benefits in addition to targeted improvements. For example, preserved areas offer parks, ponds offer beauty and habitat, clean streets are more attractive, education helps empower people, and sediment control improves fisheries and prevents flooding.

Conclusion

Many fine handbooks provide theoretical and technical guidance concerning the design and implementation of effective stormwater pollution prevention and control measures. This study took a different approach and focused on existing effective programs in a variety of settings. In doing so, it accomplished two key goals. First, the study demonstrates that stormwater management is quite possible. The case studies show on a practical level that stormwater management can be environmentally effective, economically advantageous, and politically feasible. Second, the case studies enable communities developing or improving stormwater programs to learn from their peers. In doing so, the case studies offer an outline for future successful stormwater management strategies.

Acknowledgments

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Integrated Urban Stormwater Master Planning

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Abstract

Urban stormwater management agencies are increasingly being called upon to address water quality and natural resources issues in addition to their traditional focus on flood conveyance. In response to this, stormwater drainage master plans have been increasingly addressing stormwater quality and, in limited cases, natural resources and habitat. This paper will describe some of the problems with traditional stormwater master planning approaches, including those where water quality and natural resources have been included as "add-ons," and the urban stormwater problems we are now trying to address which have resulted from these approaches. A framework for how communities can develop integrated stormwater master plans that address multiple objectives, as increasingly mandated by public concern as well as by regulations, will be presented. Given that the tools available for master planning are not equivalent in their numerical evaluations, new procedures and project approaches are required. Especially important is how the hydrology/hydraulic methods are performed, including both flood evaluations and evaluation of the smaller channel-forming storms.

Communities are often not institutionally organized to address multiple objectives. Master planning has traditionally been led and performed by engineers trained in hydrology and hydraulics, and they are usually in different departments from those who are responsible for other environmental aspects of the drainage system. This paper will focus on the technical, institutional, and process-oriented aspects of how master planning can be improved. Several case studies from the Pacific Northwest of the United States will be discussed.

Introduction

The purpose of this paper is to discuss some of the attributes of urban stormwater master planning and how those master plans can be improved to more fully address issues besides conveyance capacity and flood control. Stormwater master plans go by a number of names, including storm drain master plans, stormwater infrastructure plans, and urban catchment management plans. These plans are usually very focused on flood control and, until just recently, address water quality minimally. This paper will discuss some of the attributes of traditional urban stormwater master planning and its results, regulatory programs (which in the US and New Zealand are requiring adifferent approach), how integrated master planning can be accomplished, and institutional barriers which often prevent integrated master planning from being accomplished. In this paper, an Integrated Stormwater Master Plan is an infrastructure and management plan that not only addresses flood control and property protection issues, but also considers stream stability and habitat, along with water quality and aesthetics.

Urban Stormwater Drainage Problems

It has long been recognized that in urban areas, unplanned stormwater management systems result in damage to property and sometimes people. As it will be well demonstrated by other papers in these proceedings, urbanization of watersheds and the resulting impervious areas also cause changes to the hydrology and water quality of receiving waters which ultimately result in other impacts to aquatic life and humans. Even some of our measures to control impacts can have unplanned detrimental effects. Especially sensitive to these changes are stream systems and coastal embayments that are not well flushed. Almost always there are also direct impacts to stream riparian areas which also increase these changes through canopy removal and channel modifications.

Urbanization usually includes impervious areas directly connected to efficient stormwater conveyance systems (including roof drains and driveways connected to streets and curbs to inlets to pipes) which then are discharged to streams directly or through engineered channels. This has resulted in stormwater being conveyed as fast as possible to receiving waters (and away from properties). Increasingly, it is being recognized that because stormwater is drained to streams in this manner, small storm hydrological changes that result in increased runoff flows can significantly increase the frequency and duration of elevated flows. This energy change within the normal wetted channel often results in channel cutting, widening, and/or sedimentation, which in turn can cause severe habitat and water quality degradation (MacRae 1996; Sovern and Washington, 1996). Often to "fix" these channel problems, streams are enclosed, hardened, and/or straightened. Even without considering the water quality of stormwater, our stormwater systems are severely impacted from a physical habitat standpoint, including habitat loss, higher velocities, and temperature changes. Figure 1 shows an example of how stream runoff can change with urbanization, including much higher and peaky flows as well as increased volumes of runoff.

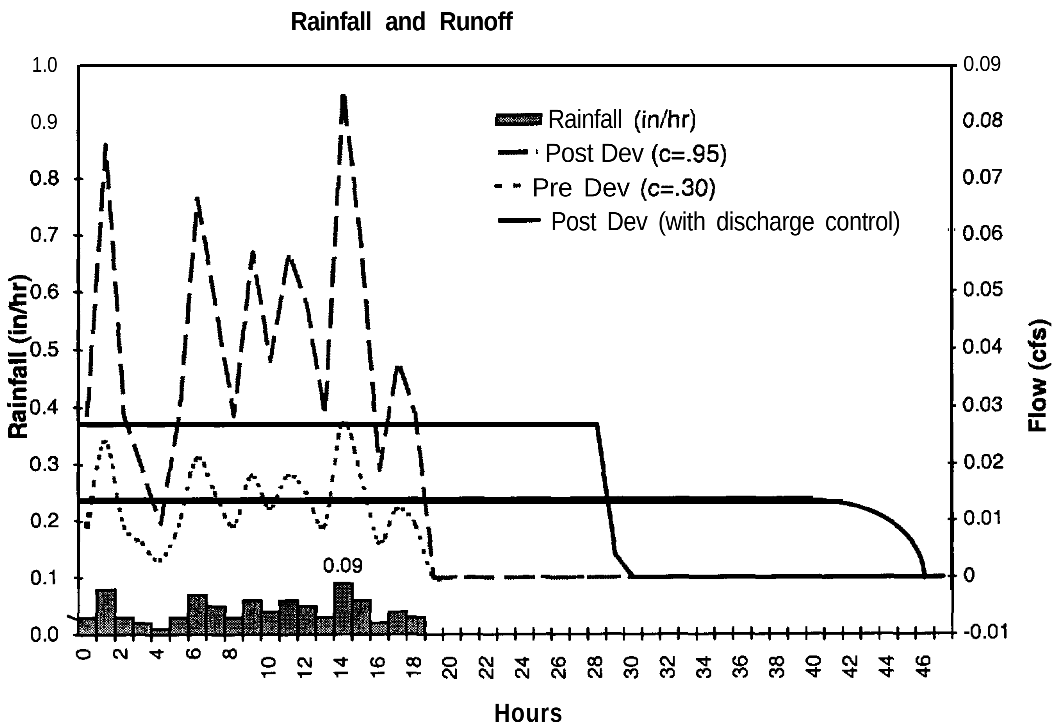
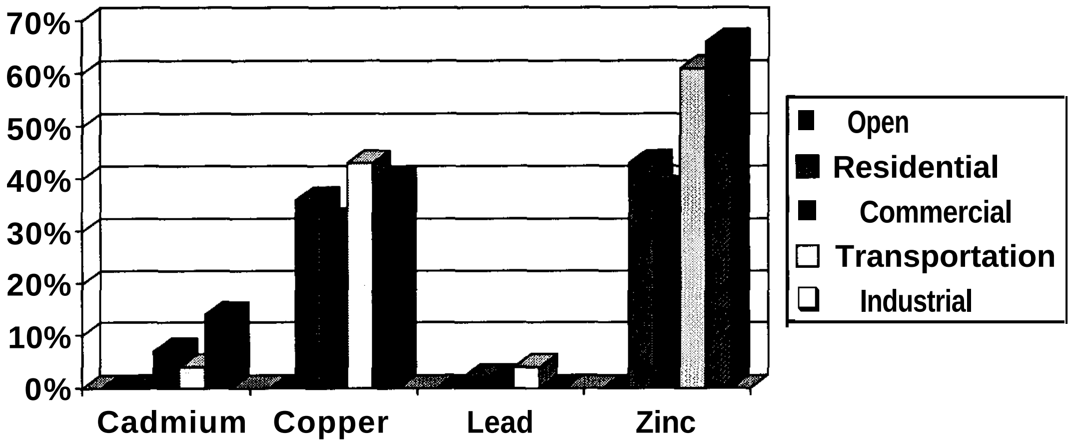


Figure 1. Example Schematic of Changing Rainfall/Runoff Relationships with Development.

With urbanization also comes a dramatic change in water quality. Urban stormwater systems are the efficient conveyance system of urban pollutants, both those discharged during storm events and those occurring during dry-weather discharges. There are numerous ways that pollutants enter stormwater from those in the rainfall itself to commonly thought of sources such as street dirt and car drippings. Stormwater often exceeds US EPA water quality criteria. Figure 2 is a graph of the frequency that stormwater runoff from identified land uses in Oregon exceed US EPA acute dissolved metals water quality criteria in runoff from identified land uses (Strecker et al., 1997). It should be noted that most of this runoff was measured in pipes, while the criteria are meant to apply to receiving waters. A data set of flow-weighted composite samples (representing average storm concentrations) from over 40 land use stations from various areas of the Willamette Valley was utilized to develop the information displayed in the figure. The stations included an open land use station in an urban area (Forest Park in Portland) for comparison. Note that dissolved copper and zinc in developed land uses exceeded criteria for 30 to 65% of the storm events. Similar findings have been found in other programs, including the San Francisco Bay area programs (Cooke and Lee, 1993).



Based upon Oregon NPDES Stormwater Monitoring Data Compiled by ACWA. Developed areas: 27 to 67 storm events; Open space: 9 storm events

Figure 2. Frequency that Flow-weighted Composite Urban Stormwater Runoff Samples Metals Concentrations Exceeded US EPAs Acute Criteria for Aquatic Life.

The water quality impacts together with the physical hydrology changes described above have caused our urban stream systems to become severely degraded. Our traditional systems have not protected the resources nearly as well as they have protected property. As many have now recognized, at about 10 to 25% imperviousness, the health of the aquatic system is severely degraded (May et al., 1997; Schueler, 1994). In many cases because of the longer-term channel stresses, property has been damaged as well, including under cutting of headwalls, etc. The plans typically only identified solutions that solved large flooding problems, sometimes just temporally until what has been considered "maintenance" problems such as head wall failures, occur.

Environmental Concerns and Regulatory Requirements

In the US, Congress has recognized that urban stormwater plays a major role in affecting receiving waters when it mandated in the revised Clean Water Act that urban stormwater water quality be addressed through a permitting (consent) program. New Zealand has similar requirements through its Resources Management Act of 1991. Both these programs are still evolving. The stormwater permit program in the US specifically requires that larger cities (over 100,000) and soon smaller cities address stormwater quality issues as they conduct flood control projects. New Zealand's program also requires that municipalities obtain consents for stormwater discharges.

Under the overall program, one area that has been slow to change is how urban stormwater master plans are developed and implemented. Although there are requirements to consider water quality in conducting flood control efforts, for a number of reasons (including institutional inertia) agencies have been somewhat slow in actually giving water quality and habitat protection equal weight with flood control in master planning. Some of this is due to the fact that stormwater master plans are typically the responsibility of engineers who are experienced in hydraulics, but that often lack experience and knowledge in other aspects of environmental stormwater management. To be fair, engineers have been told to plan for managing stormwater based upon land-use zoning that was selected without considering stormwater issues. Another major issue is the resources allocated to conduct integrated planning efforts which are more expensive; often agencies do not recognize the value of better up-front planning compared to capital and maintenance costs.

Increasingly though, the public has started to demand that more environmentally sound and/or aesthetically pleasing stormwater management approaches be utilized. For example, with the endangered species act (ESA) listings and proposed listings of salmon and trout species in the US Pacific Northwest, many neighborhood organizations are pressuring municipal agencies to change their stormwater management approaches. Some of these efforts are having more success than the regulatory programs.

Stormwater Management Agency Functions

Understanding a stormwater management agency's function and history is important to understanding its approach to stormwater management. Stormwater management agencies typically fulfill the following roles:

1. Stormwater System Maintenance
2. Development Standard
3. Stormwater Master Planning
4. CIP Design and Construction
5. Funding-Utilities/System Development Charges
6. Stormwater System Permitting and Environmental Impact Minimization
7. Education

The last two elements are the most recent. Many agencies began by responding to emergencies and problems, and were then tasked to develop onsite design conveyance standards. Stormwater master plans for the most par-t were developed in response to problems that arose after watersheds were developing with little or no stormwater planning. They also were typically focused on just flood control and property protection. Most often they focused on the piped systems and road culverts. Often creeks away from culverts were not evaluated unless there had been a particular problem identified. In the US, the Federal Emergency Management Agency (FEMA) had separately developed flood plain maps for larger systems, which communities relied upon for protecting structures from larger river and stream flooding. This was done to meet requirements for participation in FEMA's flood insurance program. Therefore, flood plains and the creeks themselves have not been a focus of master plan (e.g., creek sections were typically not evaluated to a great extent).

Stormwater Drainage Master Plan Goals and Results

The traditional purposes of the Stormwater Drainage Master Plan were to:

- Guide a city's stormwater drainage system capital improvement project (CIP) program. (e.g., identify, select, cost, and prioritize stormwater system construction projects.)
- Establish a maintenance program for the stormwater system (recommended stormwater system maintenance practices and frequencies)
- Establish onsite conveyance requirements (design standards for level of peak flow conveyance by an engineered stormwater system and, sometimes, requirements for street conveyance of stormwater beyond the onsite requirements)

Master plans seldom included requirements for development with regard to stormwater system impacts (e.g., downstream flow and/or water quality impacts). Master plans were sometimes utilized to assess potential future problems as well as to fix existing problems. Often systems were evaluated under current conditions and future planned zoning to be able to assess costs to current rate/tax payers or new developments. Because master plans were not usually completed prior to some significant level of development, attributing these costs was important to the development community as well as to the residents.

The traditional approach to stormwater master planning has been to focus on hydrology and hydraulics of the existing stormwater systems, and proposed larger trunk systems to determine whether there is enough capacity. This is usually is accomplished by the following steps:

- Route a designated large storm through system, assume worst case conditions (saturated, etc.) and determine capacity deficiencies

- Develop an enlarged (or more efficient) system to handle larger flows or, when necessary, reduce peak flows by detention (if the cost of detention is less than a conveyance upgrade)

- Sometimes consider water quality as a "add-on" (e.g., if detention is required, claim a water quality benefit)

This approach has certainly significantly reduced property damage (sometimes only for short-term), but has led to more damage in streams. The damage has been a result of a significant increase and duration in small storm runoff flows. The result of not planning for this increased energy, which is primarily contained within the stream channel, has often been an increase in maintenance and property damage. For example, channel cutting that occurs upstream of culverts often causes headwall and culvert failures. In other areas where channel cut sediments settle out (often in over-designed or poorly designed culverts), areas are filled in with sediments. When this occurs (especially in a culvert), it can lead to flooding. These problems (headwall failures, culverts filled in, etc.) are often called maintenance issues, when they are in fact really failures of the master plan to adequately address stream impacts of development.

Typically smaller urban stormwater systems (e.g., 10 to 50 acre catchments) are dominated from a flooding standpoint by shorter-duration, more-intense storms (thunderstorms), whereas, the larger urban watersheds are often impacted by larger, but less-intense storms of longer duration. Master plans typically utilize a single large design storm event based upon a rainfall depth (mm of rain over a watershed) for a specified duration and return period. This depth is then assigned a conservative shape such as the SCS type IA shape shown in Figure 3). The storm shown is the 25-year, 24-hour storm depth for Eugene, Oregon, with the SCS distribution applied to it. As an example of how overly conservative the peak of

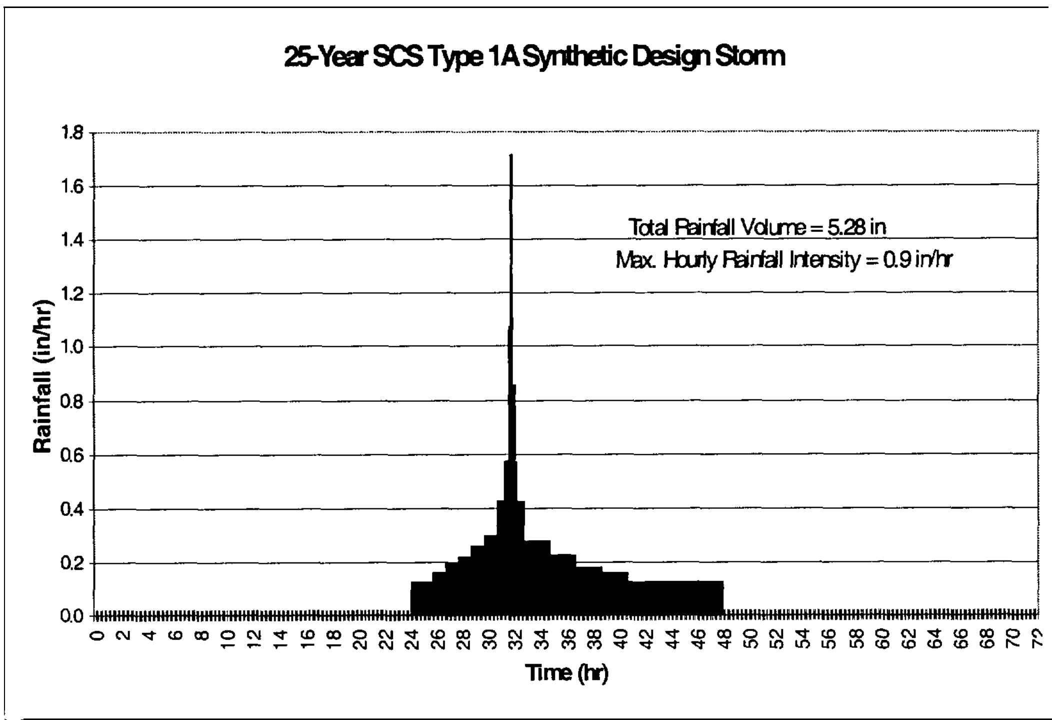


Figure 3. 25-Year, **24-Hour** SCS Type **1A** Synthetic Design Storm for Eugene, Oregon.

the “design” hydrograph is, Figure 4 shows an actual 25-year storm hydrograph (based upon analysis of the Eugene Airport rain gage). This storm was confirmed by long-term simulation modeling to have caused approximately the 25-year return-period flows in the larger stormwater systems in the city. In reality, the 25-year return-period storm depth seldom if ever arrives with the peaky “shape” given it in master plans.

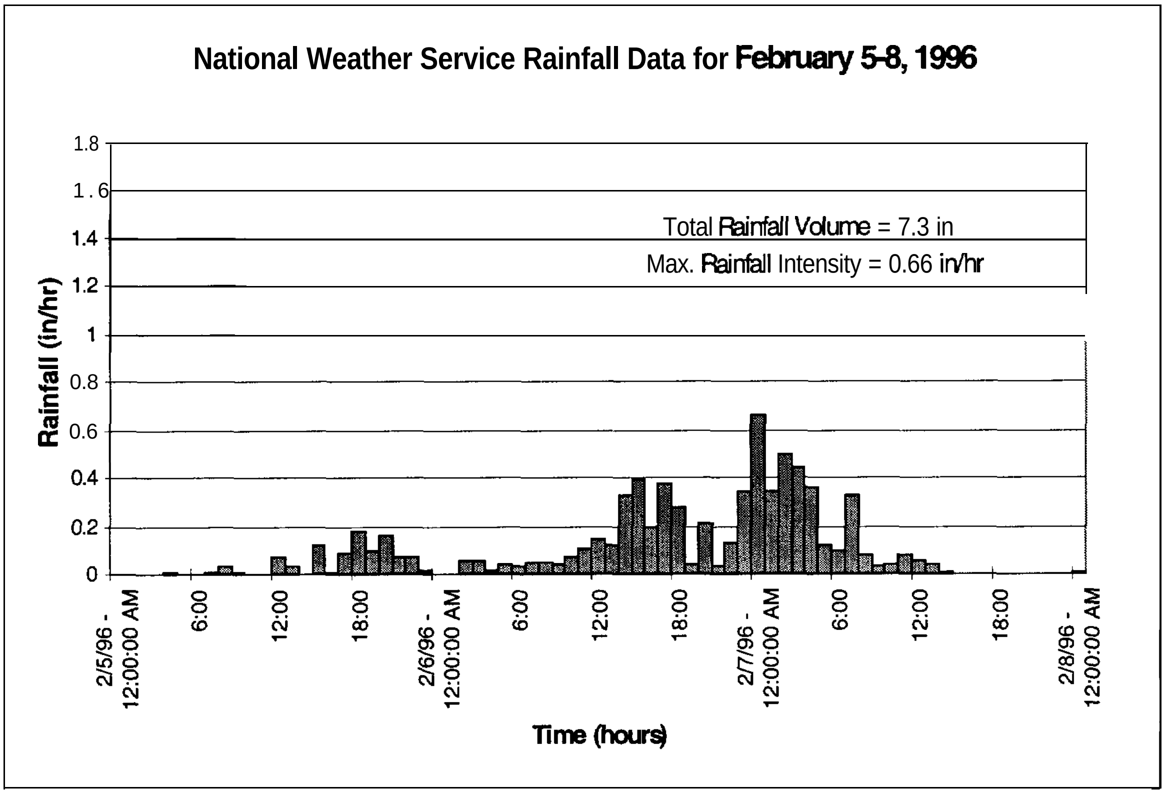


Figure 4. Rainfall Event that was Considered to Cause the Approximately 25-Year Return Period Peak Runoff Flows in Eugene, Oregon.

Many have justified this shape as being one that will also allow flood control effects of smaller thunderstorms on the smaller stormwater systems to be adequately evaluated. When the peak is modeled in this fashion on a larger watershed during an already large rainfall, the peak may greatly affect the larger system design. This conservative design approach we believe has led many communities to determine that streams are undersized and must be widened, channeled, and/or piped.

Of course in communities where there is the potential for combined phenomenon to cause severe flooding (e.g., snowmelt and frozen ground combined with a hard rain), there may be good reason to over size facilities. However, in most cases, it may be more appropriate to utilize methods that account for this and to strive to preserve open channels in more natural ways (e.g., larger stream buffers) to the extent possible.

Another assumption that is often made is that the watershed is saturated before the design storm arrives. This assumption is made to be “conservative.” However, it results in an uneven level of conservatism. This assumption would tend to lead to the most over-designed conveyance systems in the least paved areas. That is, the saturation assumption would tend to make systems most over-designed in low-density, single-family areas vs. less over-designed in the downtown core area. The point here is that the levels of over-design are not consistent, nor targeted to the areas where the greatest level of protection is desired (highest property value).

Finally, water quality, and sometimes habitat, is only now being considered in master planning. This is most often accomplished by adding water quality to a detention feature or specifically selecting and locating several demonstration water quality projects. Some communities have chosen to not emphasize habitat by engineering their streams with the purpose of providing flood conveyance as recreational amenities. The Denver area is a good example of this type of design. In arid areas, where streams are seasonal or even just storm driven, this may be a good choice for communities. However, some communities are considering the value of seasonal streams play for downstream resources from a biological and water quality perspective. For example in Eugene, Oregon, the city has determined that seasonal streams contain a rich fauna of aquatic invertebrates (WCC, 1995) which likely would benefit the health of downstream systems.

There are a number of reasons why the above approaches have continued to be employed. First, planning that considers multiple objectives is much more difficult to accomplish, from the technical approaches, due to the need to involve more parties in decision making. The traditional technical approach described above is straightforward, while design of more natural systems is not (e.g., pipe flow equations are much easier to utilize then open channel flow in natural streams). In addition, there are many more people to involve in making decisions than dealing only with engineered physical structures within the stormwater system. Second, most municipalities are not organized well for the purpose of urban watershed planning. The City of Portland, Oregon (which has been very progressive in many ways) still has four separate departments (all in one bureau) that do: 1) facilities planning (stormwater system master planning), 2) site stormwater standards, 3) stormwater quality (permit compliance), and 4) watershed management. Each of these groups has developed its own plans and programs that have understandably not been very well-coordinated or integrated. Finally, and probably most important, is that integrated planning studies cost significantly more (on the order of 2 to 4 times as much).

Integrated Storm Drainage Master Plans - Approach

The new approach to stormwater master plans is the integration of flood control, water quality, natural resources, and aesthetics of stormwater systems. This approach requires significantly more effort and should be thought of as one that will entail adaptive management. That is, the master plan must include components that allow for changing conditions as development occurs and the downstream systems react.

In completing a stormwater master plan, it is difficult to achieve “maximums” of flood control, water quality, natural aquatic habitat, and aesthetics. It is somewhat analogous to the rule that it is hard to get a cheap price, good service, and high quality. It is our belief that one of the problems with master plans has been a lack of recognition that streams will change and that the plans should be developed to manage change in a positive fashion.

One of the keys to successful integrated master planning is that the planning approach places the proper emphasis on the technical and decision-making processes employed. As mentioned above, master plans typically have been driven by the hydrologic/hydraulic modeling of large storm(s) and usually begin with model data collection and analysis. Figure 5 presents a suggested flow diagram for an alternative way of sequencing the development of a master plan. It begins by conducting an inventory of all aspects of the stormwater system, including all attributes related to the multiple objectives mentioned above. The approach suggests utilizing multi-disciplinary teams to review conditions in the field to look for opportunities for meeting objectives, as well as reviewing existing and suspected future problems. Next, before any modeling is done, the project team and decision-makers should utilize the collected information to develop goals and objectives for the plan. Then additional technical analyses, including where and what type of detailed hydrologic/hydraulic modeling is appropriate, can be decided upon based upon these objectives. We have found this approach sharpens the focus of modeling so that the model is not “driving” the master plan into solutions that focus primarily on conveyance upgrades.

In developing an integrated master plan, it is generally understood that the right mix of multi-disciplinary technical specialists should be involved. In addition, it is important to involve the “right” decision-makers and stakeholders early in the process. It is also important to agree up-front upon the decision-making process that will be utilized. We have found that utilizing an agreed upon set of factors to evaluate, select, and rank projects is very useful not only for guiding the process more objectively, but also to serve as a history of why certain projects were recommended and why others were not. This is very useful for future decision-makers for two reasons. First, when questioned by others, there will be

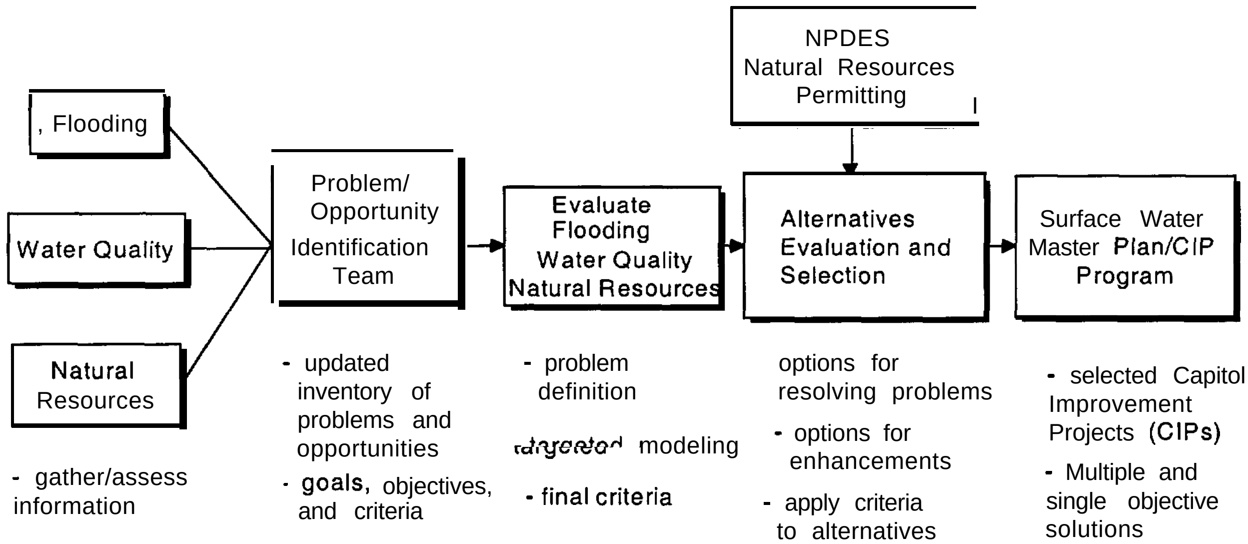


Figure 5. Suggested Integrated Stormwater Master Plan Project Approach.

some backing for why certain decisions were made. Second, as conditions that affect the factors change, selection of projects can also change in a logical fashion.

The approach we recommend is to evaluate solutions that are primarily single objective rather than those that are multiple objective. That is, a two-stage decision process is employed to make sure that good single-objective solutions are not ignored because of the multi-objective nature of the factors. The factors employed include:

- Addresses flooding problems
- Addresses water quality pollutants of concern
- Meets community amenity objectives
- Habitat value
- Life-cycle costs
- Meets regulatory requirements
- Implementability
- Reliability/sustainability
- Other environmental impacts
- Equability

Integrated Storm Drainage Master Plans - Hydrology

Integrated stormwater master planning includes evaluating and considering smaller storm hydrological impacts. Figure 6 presents a storm-depth frequency curve for Portland, Oregon. The figure demonstrates that storms of a depth of 1.5 inches and less dominate both the number of storms (more than 95%) and the volume of runoff (over 90%). It is the smaller storms of about 0.3 to 0.8 inches in depth that change the most in their characteristics. In natural areas of the Northwest, these often did not result in appreciable runoff or resulted only in slightly elevated flows for a long duration. However, after urbanization, these storms are causing severe and rapid changes in flow levels with each storm. This kind of analysis can be used to assist decision makers in deciding what level of water quantity and water quality control is going to be the most cost-effective in reducing the impacts of urbanization.

The best hydrologic and hydraulic modeling approach for assessing and designing stormwater systems is likely the use of continuous simulation models using long-term rainfall records to evaluate a system under a wide range of varying hydrologic conditions. However, this is quite expensive. One of the approaches that we have been taking is to utilize long-term simulations of stormwater systems to select design storms. We believe that this improves the consistency in providing design storms that are closer to the level of protection that is being "advertised," without having to run long-term simulations. This approach involves using real rainfall data with continuous simulation models (e.g., SWMM) to define the resulting return frequency of runoff peaks in various parts of the stormwater system. Then, real storms are selected

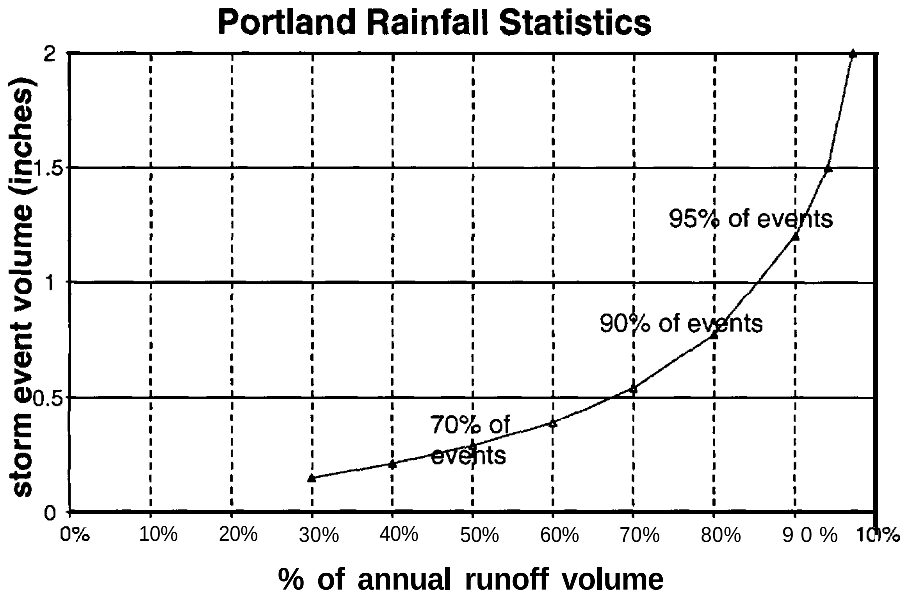


Figure 6. Cumulative Storm Event Rainfall Depth Analysis for Portland, OR Airport

that resulted in the return period of interest (using a partial duration frequency analysis). These "real" storms are then utilized to design the system. Figure 7 presents an example of partial-duration frequency evaluation of peak flows in one of the basins in the Eugene, Oregon area. From this frequency distribution, the storm that was closest to the intended design level (25-year) was selected for design analysis of the system. Figure 8 shows a similar analysis for another basin in Eugene, along with the design flows from an earlier master plan (which utilized the traditional SCS storm method with saturated conditions).

What Figure 8 demonstrates is that in this basin, the more traditional approach would have resulted in what is likely a significant over-design of the system. In most basins, this was found to be the case. However, there were several basins that were close and a few where the real storm approach resulted in larger designs. Figure 9 and 10 compare the resulting designs in the Flat Creek basin in Eugene. Note that the real storm approach resulted in fewer and smaller projects in this basin. This means that the city can utilize more of its scarce resources to complete other types of multi-objective projects. One of the advantages of the use of real storms is that the concept is very easy to communicate to citizens. In addition, the city has found that some of its channels are over-designed compared to the stated level of protection, and that they may be able to relax vegetation maintenance requirements to allow for more natural channels. Overall, the city is finding that allocating sufficient resources to conduct an integrated plan will likely lead to a more cost-effective program overall, in terms of multiple benefits.

Integrated Storm Drainage Master Plans – Water Quality

There are a number of stormwater quality models and approaches (Donigian and Huber, 1991). Some are quite simple and straightforward, while others are much more complex. In general, water quality models currently cannot accurately predict how pollutants get into stormwater. Although some researchers have made great strides in establishing sources of pollutants in the urban environment (Pitt, 1993), there still are numerous pollutant sources that are not fully understood. Most models rely on either some land-use-based concentrations to drive water quality predictions or they use a build-up/wash-off function to describe pollutant concentrations (Donigian and Huber, 1991).

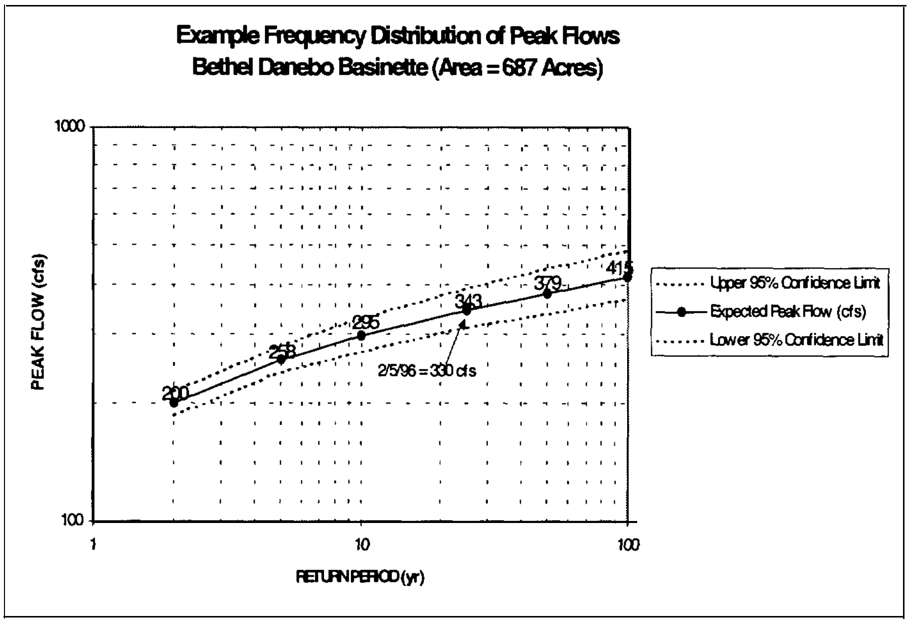


Figure 7. Example Frequency Distribution of Peak Flows in Eugene, OR.

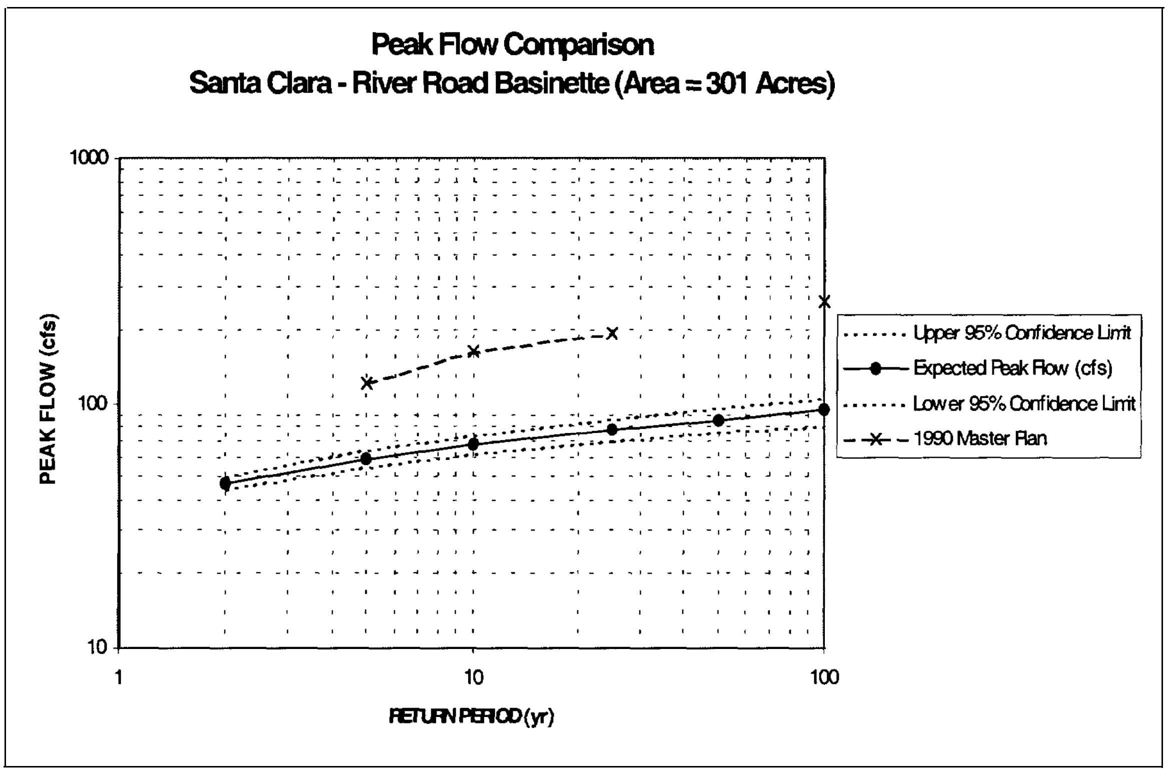


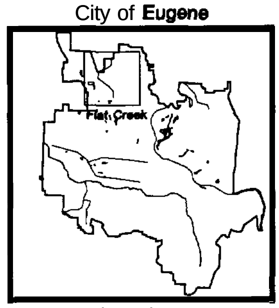
Figure 8. Peak Flow Comparison in Urban Runoff from Eugene, OR.

Flat Creek Drainage System

Capital Improvements Proposed in 1990 Master Plan

Using lo-year SCS Synthetic Design Storm

City of **Eugene**



Enlarged Area

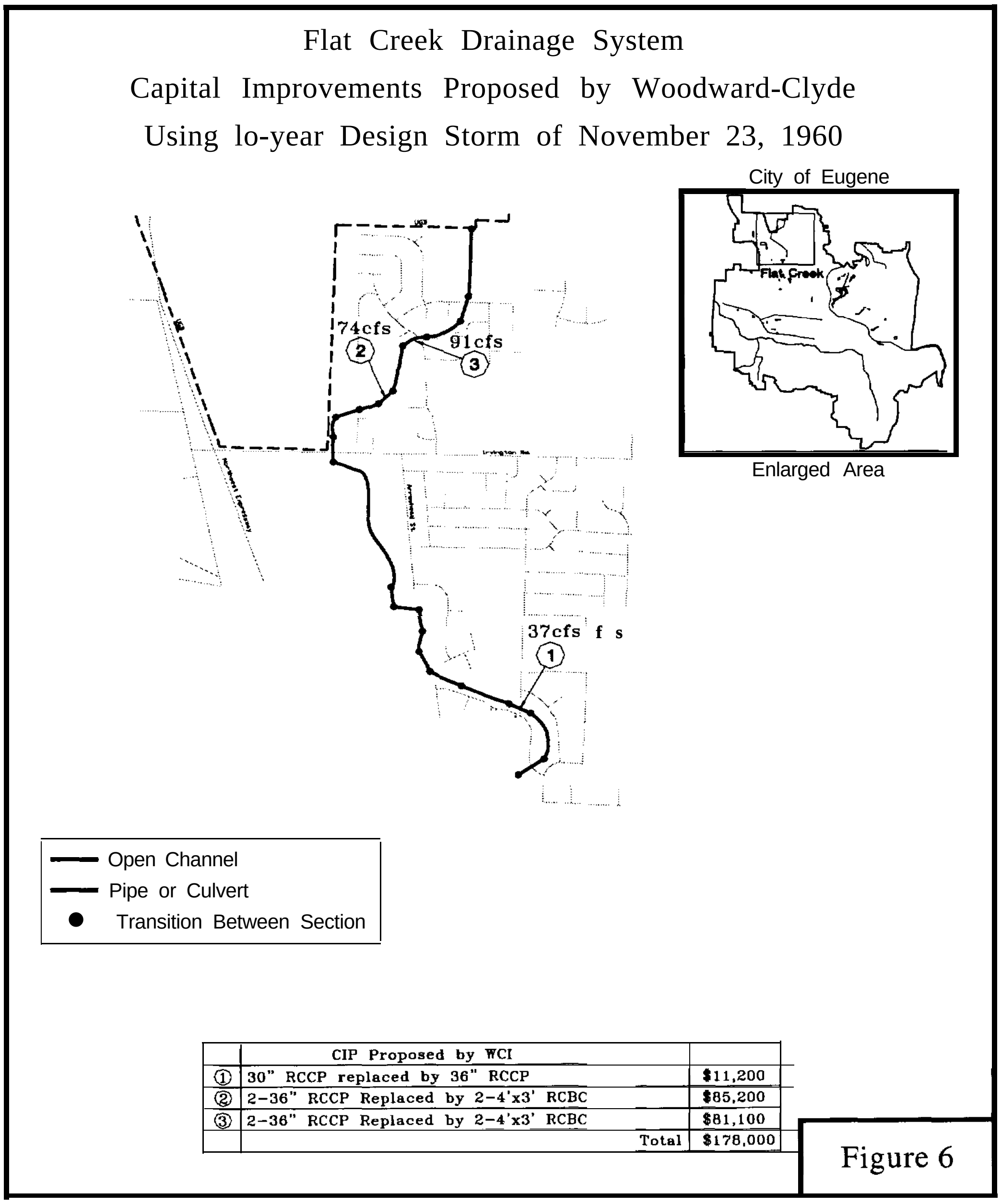
- Open Channel
- Pipe or Cukert
- ● Transition Between Section

	CIP Proposed in 1990 Master Plan	Cost
①	30" RCCP replaced by 4'x3' RCBC	$27,300
②	open channel replaced by 2-36" RCCP	$175,400
③	30" RCCP replaced by 2-3'x3' RCBC	$31,800
④	existing channel expansion	$9,100
⑤	existing channel expansion	$3,900
⑥	existing channel expansion	$21,000
⑦	3-43"x27" CMP replaced by 2-6'x3' RCBC	$87,100
⑧	2-36" RCCP replaced by 2-4'x3' RCBC	$81,100
⑨	58"x36" and 24" CMP replaced by 2-5'x3' RCBC	$117,100
	Total	$553,800

Figure 7

Figure 9. Proposed Conveyance System Improvements Utilizing the SCS Type **1A** Synthetic Design Storm and Assuming Saturated Conditions.

The build-up/wash-off of suspended solids (TSS) is modeled and then TSS concentrations are utilized to predict other concentrations for such parameters as phosphorus and heavy metals. The first problem with this approach is that it assumes that the build-up/wash-off of TSS is much greater than any other source pathway. This has not been found to be the case (Pitt, 1993). When build-up based/wash-off models are calibrated to real data, the build-up/wash-off function must be set to be much larger than it really is in order to match actual data. When a source control such as street sweeping is applied, the model will then significantly overestimate its effectiveness no matter what the assumed street sweepingefficiency is. This may explain why street sweeping has seldom if ever been found to be as effective as predicted. The second problem with these models is the assumption that other constituent concentrations can be related



	CIP Proposed by WCI	
①	30" RCCP replaced by 36" RCCP	$11,200
②	2-36" RCCP Replaced by 2-4'x3' RCBC	$85,200
③	2-36" RCCP Replaced by 2-4'x3' RCBC	$81,100
	Total	$178,000

Figure 10. Proposed Conveyance System Projects Utilizing Selected Real Storms for Design.

to TSS concentrations. Strecker (1997) presented data on TSS vs. metals relationships for Portland, Oregon stormwater data. Although the correlations were significant (r^2 of .3 to .4), we do not believe that they are high enough to be utilized without some stochastic functions employed. We believe that many master plans have utilized over-complicated stormwater pollutant load models that have not represented the actual processes well and have not resulted in better plans compared to their cost.

Based upon the above, we believe that the proper approach to assessing water quality in master planning is to utilize land-use based, simpler spreadsheet-based statistical models for water quality assessments and planning. If hydrologic/hydraulic based solutions are being contemplated then more complex models (such as SWMM) can evaluate detention times might be called for.

There have been a number of attempts to develop a better understanding of how stormwater quality BMPs work and why (Strecker, 1992; Brown and Schueler, 1997). However, what we know about the effectiveness of stormwater best management practices in improving water quality and ultimately aquatic health has been questioned with good reason (Strecker 1994; Urbonas 1995; Maxted and Shaver, 1996). Some of the questions arise from the actual studies and how they have not been completed as to be very useful in assessing effectiveness. In addition, there have been suggestions that pollutant removal efficiencies may not be the best way to assess effectiveness (irreducible concentrations, etc.).

Finally, there have been some studies that have shown that downstream of some BMPs (e.g., detention systems), aquatic invertebrate populations are no different from systems that do not have such in-stream ponds (Maxted and Shaver, 1996).

What we know is the application of BMPs is an evolving science and that the exact cause and effect relationships are not well known. However, we do know that BMPs have been effective at reducing concentrations. In cases where there has been no downstream improvement in aquatic invertebrate health from BMPs, we should ascertain what the limiting factors are and whether the BMP was able to mitigate some if not all of them before we dismiss a BMP. In addition, we need to understand whether other attributes of the BMP may be contributing to downstream problems such as demonstrated downstream temperature impacts (Galli, 1991) of on-line ponds, as well as the interruption of drift of aquatic invertebrates downstream. It is becoming increasingly clear that within-stream detention systems need to be very carefully evaluated before they are selected as BMPs. What we will need to do in master planning is to make good subjective decisions regarding the appropriate application of BMPs for water quality. We do not have the data and models to do otherwise.

Integrated Storm Drainage Master Plans – Stream Stability/Habitat

Unless a watershed has a great ability to infiltrate stormwater or evaporation is a viable technique, stream hydrology will change (increased runoff) with development. While there are some great techniques to reduce the changes (e.g., Prince Georges Department of Environmental Resources. 1997), in many cases these techniques will not be able to reduce the increased energy within a stream enough to stop channel cutting and downstream sedimentation from occurring. A technique that has been employed in an attempt to prevent downstream damage is the requirement that new development controls runoff from a one- or two-year event such that pre- and post- development peak flows for that event are equaled. MacRae (1996) has demonstrated that this approach may actually cause more problems then it solves. It usually leads to shifting over-bank flow energy to the wetted channel, further exacerbating channel down cutting. Figure 1 demonstrates this. Suppose that the peak **in** hour 14 was the one-year pre-development flow for this creek. Maintaining post-development flows to this level would significantly lengthen the time the creek is subject to this channel-forming flow condition, while reducing over-bank flows. Even setting post-development peak runoff rates to one-half pre-development, results in significant extended energy in the channel. One would likely have to set a requirement that the flow rate be one-fourth or one-fifth to have a positive effect. This would require very large detention areas.

In many, if not most cases, we believe that the master plan must include within-stream structures to assist it in changing with development (Sovern, 1996). That is, the plan must move beyond just getting runoff to a stream and making sure any culverts in the stream are “right-sized.” Master plans should include a component to design in-stream structures (habitat friendly ones, of course) and have an adaptive management program for them. This approach has been successfully applied to the Pipers Creek and Thorton Creek watersheds in Seattle, both heavily urbanized watersheds. What this can accomplish is much faster and more postive equilibrium for the stream system (e.g., the increased energy can be utilized to create deeper pools and increased spawning gravels in the pool tailway).

Integrated Storm Drainage Master Plans – Capital Improve Projects (CIPs)

The above integrated stormwater master planning elements will result in changing the traditional definition of what a CIP is. Traditionally it has been structural controls located within the municipally owned stormwater systems (e.g., the streets and street drainage structures and at creek crossings, etc.) Now CIPs can include property or property rights acquisition, buffer areas, protection and enhancement of natural resource sites and preservation of the open channel drainage system.

Integrated Storm Drainage Master Plans – Public vs. Private Solutions

Another element of master planning can include the evaluation of the trade-off of requiring private solutions (e.g., on-site design requirements) versus implementing public stormwater system measures. Figure 11 shows schematically that on a watershed basis, one could employ a combination of both to achieve the overall most cost-effective system. This can be addressed in modeling and cost-estimation for both approaches and then one or some combination employed.

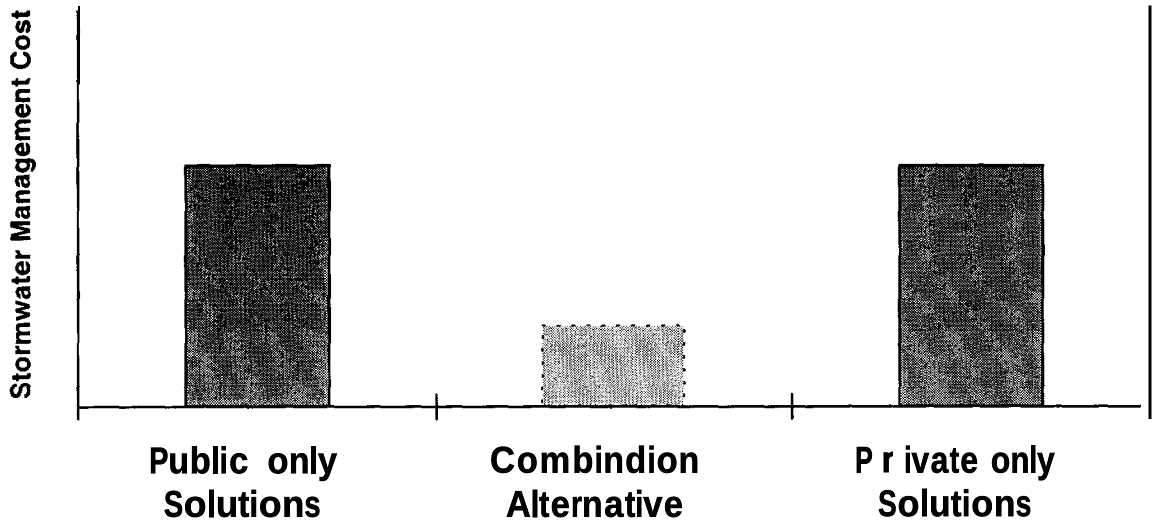


Figure 11. Conceptual Comparison between On-site Private Stormwater Solutions and Public Solutions.

Summary

In summary, urban stormwater management involves a complex set of phenomenon to manage and our stormwater science is lacking to support solely science-based decisions. Urban stormwater master planning needs to be conducted as an integrated planning and implementation process that considers water quality, habitat, and aesthetics along with urban flooding in order to meet increasing regulatory and environmental demands of the public. Typically, BMPs will only reduce the increase in small-storm hydrology that impacts physical stream habitat and stormwater pollutants; in-stream stability measures are needed as a part of master planning and urban system. Master planning and implementation needs to be thought of as an iterative process that will require adaptive management over time. A balanced approach that places the proper emphasis on problem definition, priority and goal setting, selection of measures/controls, participation by stakeholders, implementation, and monitoring/feedback/plan refinement is needed.

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Conservation Design: Managing Stormwater through Maximizing Preventive Nonstructural Practices

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Abstract

Unlike conventional methods of stormwater management that prioritize peak rate control to mitigate post-development downstream flooding effects, Conservation Design first aims to prevent or minimize the creation of stormwater from the outset. *Preventive* Conservation Design methods are defined in this paper as those that integrate stormwater management into the initial stages of project design, instead of waiting to consider them in the final steps of the site planning process. Mitigative Conservation Design techniques will be explored that use natural processes performed by vegetation and soil to mitigate unavoidable stormwater runoff impacts once prevention has been maximized to the greatest extent possible. Underlying these techniques-whether preventive or mitigative in nature-is a comprehensive perspective of water resources that views stormwater as an asset to be managed, not a waste for disposal.

This paper summarizes a recent project which the Brandywine Conservancy undertook for the Delaware Department of Natural Resources and Environmental Control, with support from USEPA Section 319 funding. For interested readers, *Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from land Development* (Delaware Department of Natural Resources and Environmental Control with Brandywine Conservancy, 1997) further details all aspects of the Conservation Design program described here. This manual is referenced throughout this paper and is available by contacting DNREC at 302-739-4411 in Dover DE.

Introduction

Most Stormwater management programs place a heavy reliance on implementation of structural stormwater managementfacilities: detention basins, conveyance piping and inlet/outlet structures. These facilities-though created to mitigate negative stormwater impacts by controlling flooding-cannot in and of themselves eliminate adverse impacts of urban development throughout a watershed. In fact, because these systems fail to acknowledge and plan for critical system-wide water cycle processes, stormwater management itself can become a problem, rather than a solution. This is especially true when conventional stormwater management systems are combined with conventional large-lot subdivision designs.

The negative effects of this type of development and conventional stormwater management have been described in a variety of recent studies and reports, including the *Pennsylvania Handbook of Best Management Practices for Developing Areas* (CH2MHill, 1998) and a variety of other state stormwater manuals; Center for Watershed Protection publications such as *Better Site Design: A Handbook for Changing Development Rules in Your Community* (Center for Watershed Protection, 1998) and *Planning for Urban Stream Protection* (Schueler, 1995); the Northeastern Illinois Planning Commission's *Reducing the Impacts of Urban Runoff: The Advantages of Alternative Site Design Approaches* (Northeastern Illinois Planning Commission, 1997), and *Urban Stormwater Best Management Practices for Northeastern Illinois* (Northeastern Illinois Planning Commission, 1993). These effects include:

- Altered site hydrology and reduced groundwater recharge
- Reduced stream base flows
- Altered stream geomorphology (resulting in damaged aquatic habitat)

- Loss of site area for other uses (e.g.; recreation)
- Single purpose: disregards site resource conservation benefits
- Lack of attention to water quality
- High construction costs
- Maintenance burdens and costs
- Negative visual appearance (e.g., basins often fenced off)
- Limited number of stormwater discharge points
- Less flexibility in design

Conservation Design reflects a totally different philosophy toward land development that integrates stormwater management into the very core of site design, as opposed to considering it a problem to be resolved after the design has been completed. This philosophy regards stormwater as a key component of the hydrologic cycle and critical to maintaining the water balance-and groundwater reserves-for a particular watershed.

Recently we have come to realize that land development's impacts to water resources are not one-dimensional. They include, in addition to flooding, the multiple concerns of water quality, groundwater quantity, stream and wetland characteristics, in-stream habitat, and biodiversity. Therefore, stormwater management and site design must be approached much more comprehensively. At the foundation of this comprehensive approach lies an understanding of the relationship between land development and our water resources. In order to better comprehend this relationship, we must understand the water cycle itself-the amount of rainfall, evapo-transpiration, groundwater infiltration, and runoff-and how this cycle is affected by the characteristics of an individual site such as soil types, topography, and vegetation.

The Water Cycle and Landscape Dynamics

Appreciation of the water cycle is especially important to achieve successful, comprehensive stormwater management (Figure 1). In fact, only through understanding full water cycle dynamics, can we hope to achieve some sort of system balance and minimize negative stormwater impacts. Figure 2 displays a generic flow chart of the water cycle that highlights the various components of this cycle and how they are interconnected **(Conservation Design for Stormwater Management, 1997).** It is important to appreciate that the system itself is a closed loop: what goes in, must come out. If inputs to infiltration are <u>decreased</u> by 10 inches, then inputs to surface runoff and/or depression storage must be <u>increased</u> by this same amount. Furthermore, infiltration <u>outputs</u> must also be decreased: following along on the flow diagram, the groundwater reservoir, evapo-transpiration and soil moisture elements together will be reduced by this 10 inches, which will reduce stream baseflows.

The logical first step in any discussion of the water cycle is *precipitation-h* all its various forms. In southeast Pennsylvania, and indeed throughout much of the Mid-Atlantic states, the climate is relatively humid **(*Conservation* Design *for Stormwater* Management 1997, based on Hydrosphere 1992 database).** Substantial precipitation tends to be distributed throughout the year in frequent events of modest size. This consistency in rainfall throughout the year indicates that this region does not have a defined wet or dry season as do other areas of the country. This rainfall potential throughout the year has significant implications for consideration of stormwater runoff. For example, having rainfall throughout the year indicates that sediment laden runoff can occur at any time; therefore, it is important to establish some sort of erosion-controlling groundcover during all seasons of the year.

Also important is the distribution of rainfall by size of event. Based on analysis of 35 years of data from a Wilmington, Delaware rain gage ***(Conservation Design for Stormwater Management* 1997)**, it is clear that the precipitation occurs mostly in small "events" or storm intensities. Ninety-eight percent of the total *number* of events during this extended period were classified in the "less than 2 inches" category. Even more important from a water cycle perspective, 96% of the average annual rainfall *volume* occurred in storms of less than 3 inches (which is less than the 2-year, 24 hour

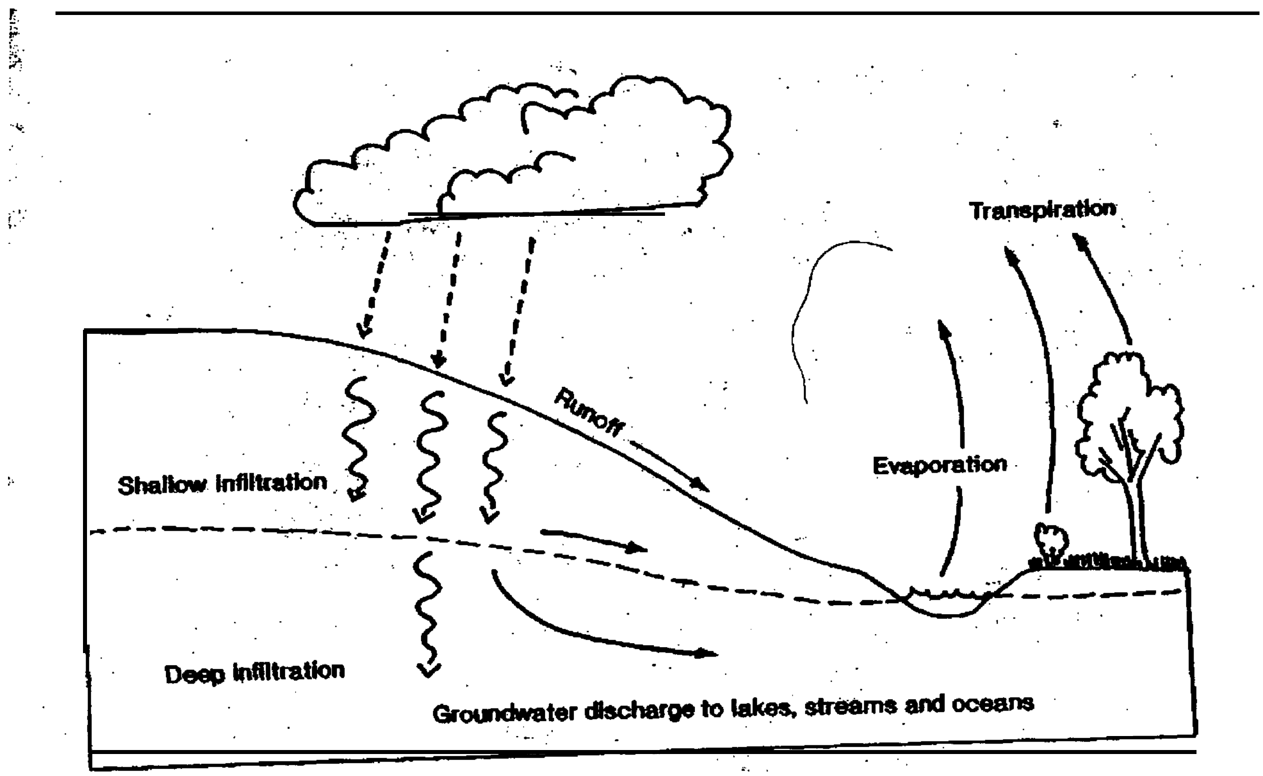

Figure 1. The Water Cycle.

storm). This understanding of storm size distribution is critical for a variety of reasons in stormwater management. For example, if our concern is keeping the water cycle in relative balance, capturing and recharging the 1 - or 2-year storm as the basis for design will encompass the vast bulk of precipitation and stormwater runoff volumes in the average year and provide adequate water cycle balance. This leads to very different design criteria than if flooding (peak runoff rates) is the only concern addressed.

Another key component of the water cycle is the linkage between stormwater infiltration, groundwater recharge and stream baseflow. As land is developed and impervious coverage increased, less water is recharged to groundwater aquifers **(Thomas Dunne and Luna Leopold's *Wafer in Environmental Planning* [Dunne and Luna, 1978] is an excellent background text in addition to the above referenced reports).** As these subtractions continue acre-by-acre, development-by-development, their cumulative effects grow larger. Also, as development occurs, more water is often withdrawn from the underground reserves for drinking, irrigation, or commercial uses, As subtractions are made from the groundwater reservoir flow, the impact will be seen in the form of a lowered water table and reduced stream baseflow discharge. Headwater springs and first-order streams-the lifeblood of our stream systems-may even dry up. The baseflow from headwater zones is critical to maintaining a diversity of aquatic plant and animal life, as well as terrestrial animals dependent on certain aquatic species for survival. In some cases the groundwater reservoir does not discharge to a stream, but rather to a wetland. In these instances, reduced infiltration and a lowered water table ultimately translate into a loss of wetlands themselves, and an elimination of their rich and vibrant ecological function.

A final component of the water cycle that must be addressed is overland runoff. This is the component most frequently addressed in conventional stormwater management approaches, for it is the cause of increased downstream flooding. Three major elements determine the volume and character of stormwater runoff for a given storm intensity: soil type, land cover (including vegetation and debris), and slopes. Soils vary widely in their ability to infiltrate stormwater and

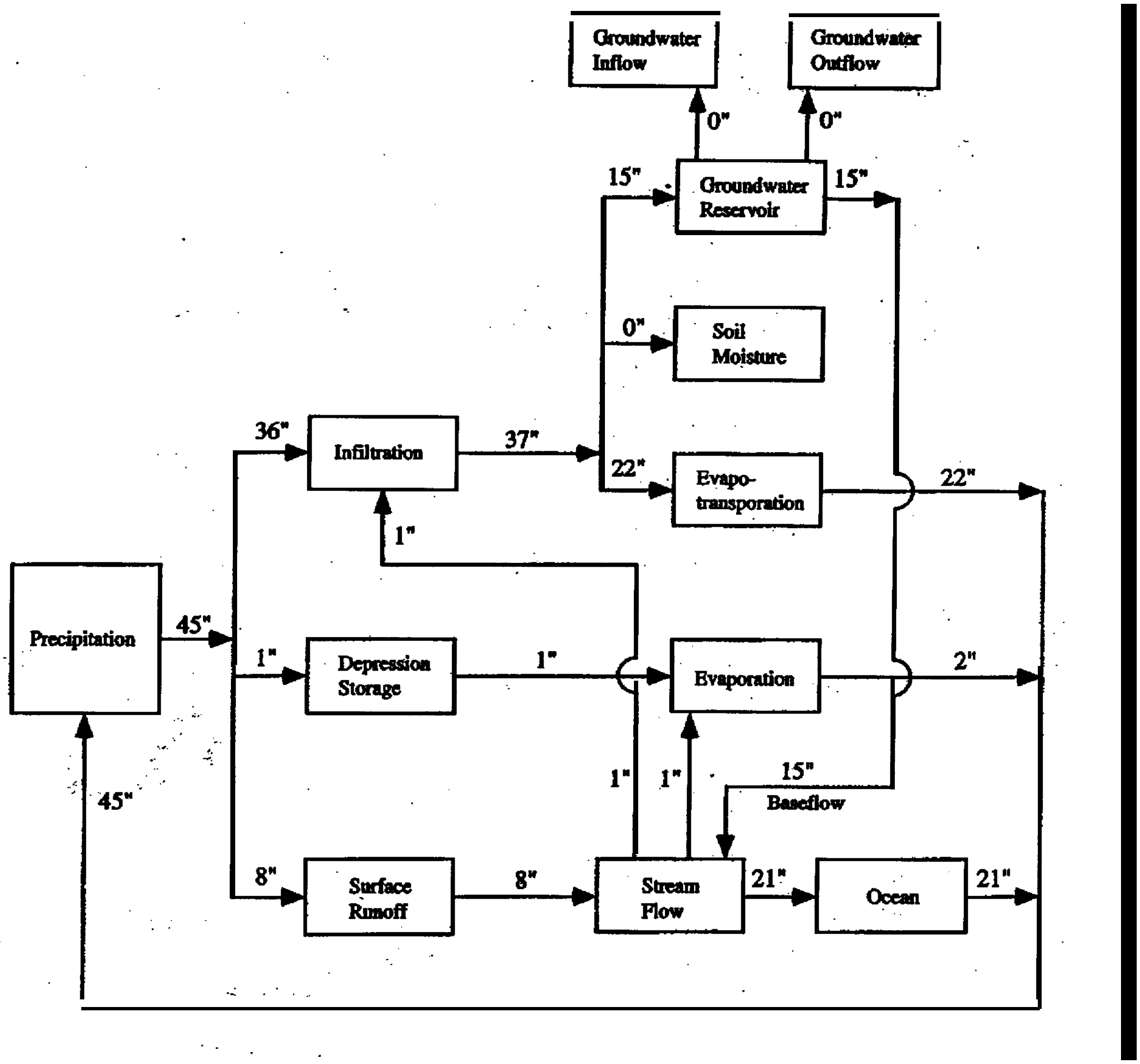

Figure 2. Water Cycle System Flow Chart.

minimize runoff and are classified accordingly by the USDA Natural Resources Conservation Service (NRCS) into four categories based on their permeability rates (Hydrologic Soil Groups A through D, with A having best permeability).

Land cover greatly affects the rate and volume of stormwater runoff and has significant water *quality* impacts as well. Obviously, the landcover of greatest concern for stormwater management is impervious coverage created through the development process. Interestingly, compacted lawns and cultivated fields can have significant runoff rates as well, especially when no crop covers the bare soil. The landcover in this region best suited to retard stormwater runoff and assist in its infiltration is the natural one: the piedmont forest. A mature forest can absorb much more water than an equivalent area of turf grass due to the presence of an organic litter layer and herbaceous and woody plant material. The organic litter layer on the forest floor provides a physical barrier to sediments, maintains surface soil porosity, and assists in denitrification and other water quality functions. The vegetation, both herbaceous and woody, physically retards runoff and erosion with its spreading root mats and also assists in maintaining soil permeability and water quality by taking up nutrients through its root systems.

Finally, slopes are another critical component of the stormwater runoff equation. Steeper slopescan accelerate runoff and increase the erosive force of the water. Therefore, removing vegetation on steeper slopes can have dramatic impacts on downslope aquatic systems.

As seen above, the water cycle and the implications for stormwater management are complex and comprehensive. The process of urbanization dramatically impacts the functioning of this water cycle. Conservation Design has been developed to address the issues of comprehensive stormwater management and to address the land use patterns that impact it.

Land Use and Site Development Impacts

Throughout much of the United States, farmland and natural areas are converted to suburban development at an ever accelerating pace. In fact there is hardly a city in America that does not occupy at least two to three times more land area than in 1970, even if population has not increased proportionately. This history of land use change is certainly true of the Mid-Atlantic states, where communities continue to grapple with the effects of unmitigated suburban sprawl.

The dynamic nature of wet-weather flow regimes and landscape ecology make it difficult to assess the impact of urbanization on aspects of the water cycle such as groundwater reserves and aquatic habitat. However, studies have indicated that the biological community in urban streams isfundamentallychanged to a lower ecological quality than what was there before development occurred. In one study in Delaware, approximately 70% of the macroinvertebrate community found in streams of undeveloped forested watersheds was comprised of pollution sensitive mayflies, stoneflies, and caddisflies, compared to 20% for urbanized watersheds (Maxted and Shaver 1996). Other studies suggest that the decay in stream quality is very rapid in the early stages of watershed urbanization; watersheds with less than 10% impervious cover are the most susceptible to the adverse effects of urbanization. Therefore early intervention as a watershed begins to develop is critical, and furthermore, this intervention should include measures to address stormwater management and land use in a connected, comprehensive manner.

In addition to in-stream habitat impacts, the issue of land development and water resources also has great implications for our human communities well beyond the issue of flooding. Reduced stream baseflows and groundwater resources means decreased availability of drinking water supplies. Also, reduced baseflows result in less available water for diluting the pollution output from industrial or municipal waste systems. As stormwater runoff increases, water quality can be greatly impacted by stream bank erosion, resuspension of sediment, runoff of chemicals and fertilizers from lawns and fields, and increased stream temperatures. Stormwater-linked pollutants vary with type of land use and intensity of use and have been shown to include bacteria, suspended solids, nutrients, hydrocarbons, metals, herbicides and pesticides, toxins and organic matter. Not only are these pollutants increased, but the landscape's natural capacity for filtering and chemical uptake through vegetation is decreased as land is cleared and paved. All of these pollutants can impact both drinking water supplies and natural aquatic systems.

Thus it becomes evident that if the negative effects of land development on our water resources are to be minimized, we must find alternatives to the conventional structural approach to stormwater management. Moreover, these alternatives must address the issue of land use and patterns of development in a comprehensive fashion, one that strives to maintain a hydrologic balance on site and replicate the pre-development hydrologic regime to the greatest extent possible. One approach-or collection of approaches-that can accomplish these goals is *Conservation Design.*

Conservation Design Principles

Stormwater management throughout the Commonwealth (and elsewhere) can be markedly improved by approaching stormwater differently than has been the practice in the past, where "stormwater management" has been defined largely as stormwater disposal. This different perspective challenges us to maximize prevention, even before stormwater becomes a problem, and to avoid highly engineered structural solutions that are expensive to build and maintain. In their place, Conservation Design focuses on utilization of natural systems and processes to achieve stormwater management objectives where feasible. At the same time, this new approach is intended to work with site resources-woodlands, soils, wetlands, etc.-to enhance their stormwater functions. The end result is a site design which minimizes stormwater generation and then mitigates the remaining stormwater in a low-impact manner, with an emphasis on groundwater recharge. Conservation Design is not so much a singular approach or solution as it is a *collection* of approaches and practices that are flexible enough to effectively address any given site and development program. Common to all these approaches and practices are several basic principles.

Achieve multiple objectives. Stormwater management should be comprehensive in scope, with techniques designed to achieve multiple stormwater objectives. These objectives include both peak rate and total volume control (i.e., balance with the hydrologic cycle), as well as water quality control and temperature maintenance. These objectives should include maintaining or improving the pre-development hydrologic regime.

Integrate stormwater management early into the site design process. Stormwater management tacked on at the end of the site design process almost invariably is flawed. To optimize comprehensive stormwater management objectives, stormwater management must be integrated into the first stages of the site planning. Stormwater impacts may even be a factor in determining type of use, extent of use, and location of the development on a site.

Prevent first, mitigate second. Approaches to site design which can reduce stormwater generation from the outset are the most effective approach to stormwater management. For example, effective clustering of units significantly reduces length of roads when compared to conventional development. Reduction in street width and driveway length can minimize impervious coverage. These type of approaches are rarely thought of as stormwater management practices, yet they achieve powerful stormwater quality and quantity benefits.

Manage stormwater as close to the source of generation as possible. From both an environmental and economic perspective, redirecting runoff back into the ground as close to the point of origin as possible, is preferable to constructing elaborate conveyance systems that increase flows and suffer from failures over time. Avoid concentrating stormwater. Disconnect, rather than connect, where feasible.

Engage natural processes in soil mantle and plant communities. The soil mantle offers critical groundwater recharge conveyance and pollutant removal functions through physical filtration, biological action, and chemical processing. Understanding how much of what type of soil is in place on any given site is essential when assessing stormwater management/water quality impacts and opportunities. Vegetation similarly provides substantial pollutant uptake/removal potential and can assist in infiltration by maintaining soil porosity and retarding runoff. In addition, naturally vegetated areas improve their stormwater functions over time as leaf litter and debris builds a richer organic soil layer. Areas of good soil permeabilities (A and B soils) and intact vegetative communities should be prioritized in prevention strategies.

A Conservation Design Procedure

The Conservation Design principles outlined above, though greatly simplified, can offer valuable guidance when approaching a particular land development project. In fact, these five principles form the basis for a Conservation Design Procedure. This Design Procedure incorporates both Preventive Approaches and Mitigative Practices. Preventive Approaches tend to be broader in geographic scope than other techniques and typically may influence some of the major decisions regarding a particular development project. Approaches may even transcend the site itself, involving an entire planning jurisdiction or area, or even an entire region. Also, Preventive Approaches attempt to reduce impervious coverage or minimally disturb the existing vegetation and soils in prime recharge areas. For example, a reduction in road width from 30 feet to 18 feet means an immediate 33.3% reduction in roadway imperviousness, which typically comprises a large portion of site imperviousness.

Mitigative Practices include mitigative techniques which are often more structural in nature. These practices encompass a rapidly growing array of biofiltration and bioretention methods that maximize the stormwater management potential of soils and vegetation. Mitigative Practices include vegetated swales for stormwater conveyance, vegetated filter strips and riparian buffers, grading, berming, terrraforming, and level spreading stormwater in natural areas. These practices should mitigate as close to the source as possible and achieve multiple objectives. For example, a berm, which is used to retain stormwater runoff on a forested slope, can double as a walking trail, thus decreasing the expense of two separate individual systems.

Figure 3 graphically displays the Design Procedure as a flow diagram. The procedure itself can be thought of as a series of questions which must be asked as Conservation Design is applied to each site. If site designers rigorously address all of these questions, the “answers”-the Conservation DesignPreventive Approaches and Mitigative

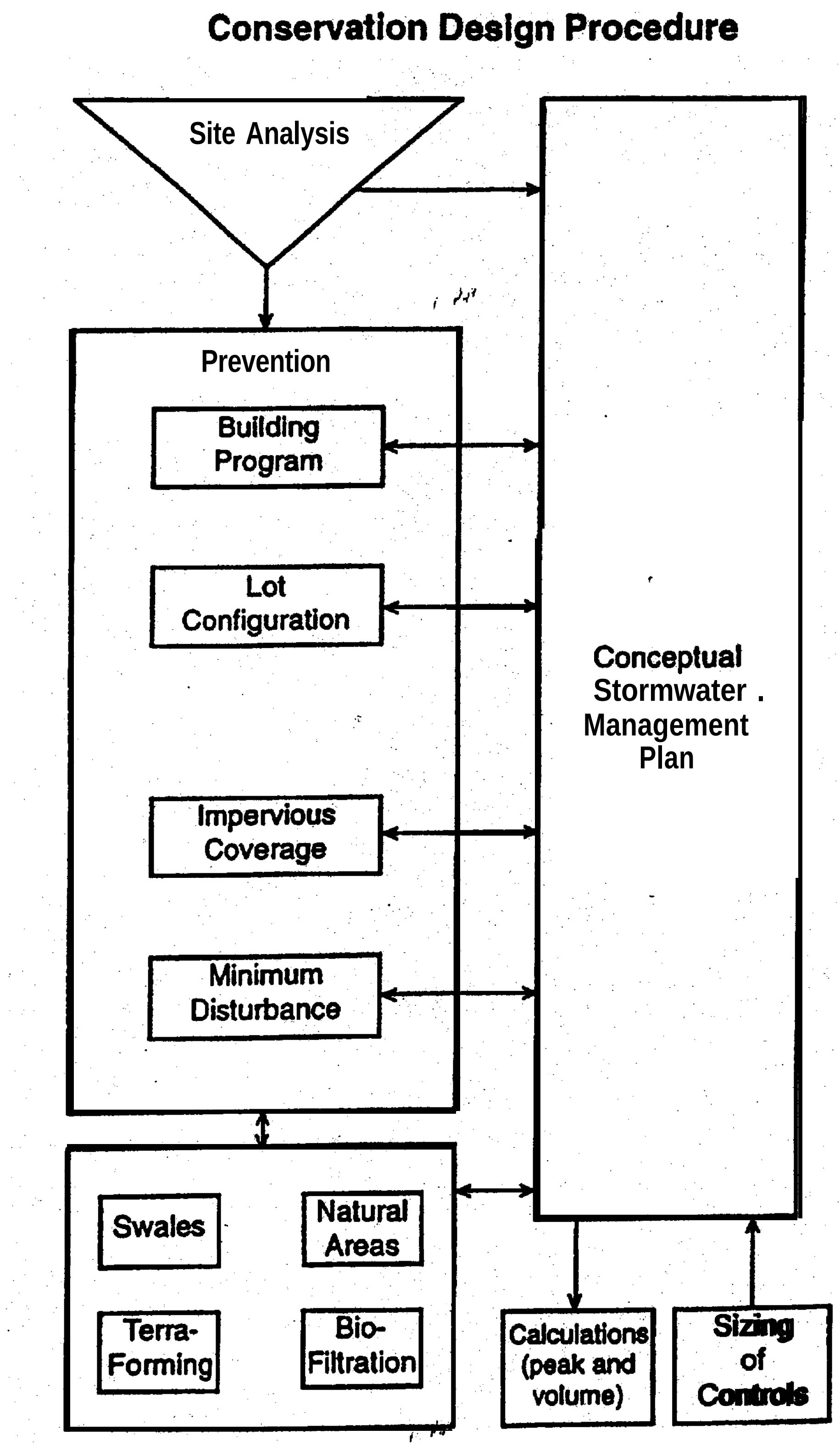

Figure 3. A Conservation Design Procedure.

Practices-will successfully be identified for each site. The overriding objective ultimately is to achieve a new way of thinking about site design. The procedure begins with an effective and complete Site Analysis, which can help identify both areas of concern and resourcesforopportunity in regard to stormwater management. The procedure then flows from macro, larger-scale preventive questions (i.e., how can the design be clustered to reduce site disturbance) to micro, small-scale mitigative questions (i.e., can stormwater be infiltrated in bioretention areas?). Probably the most important aspect of the procedure in Figure 3 is its positioning of the Conceptual Stormwater Management Plan as a concurrent task with the entire site design process. This reinforces the notion that stormwater management should be an integral part of the entire design process, including the site analysis.

In order to better understand the Conservation Design Procedure, each of its components (the Preventive Approaches and Mitigative Practices) is discussed in more detail below.

Site Analysis

Three major aspects need to be addressed in the Site Analysis process:

Site Background and Context

What is the surrounding context?

What is its location in the watershed?

In which geologic/geographic region is it located?

What is the site size?

What are adjacent uses and landcover?

Critical Natural Features

Existing hydrology?

Wetlands? Floodplains? Riparian buffers?

Steep slopes? Special habitat areas?

Stormwater Opportunity Areas

Where are soils that are best suited for stormwater recharge? Worst?

Where is existing landcover optimal to prevent stormwater?

What opportunities exist to use vegetation and soils in mitigation?

On what soils and slopes is this vegetation?

What is depth to bedrock or water table?

Preventive Approaches

The Preventive Approaches include a range of hierarchical questioning:

Building Program

What is the current zoning and density for this tract?

Is there currently an open space design option for the site?

Can the proposed building program be reduced in terms of density?

Can the type of unit or lot size be modified to promote open space?

What are the possibilities for water and sewer supply?

Lot Configuration

Have lots been reduced and open space been maximized?

Have lots been clustered to avoid critical areas of recharge?

Have lots been configured to take advantage of mitigative practices?

Impervious Coverage

Has development been clustered to reduce impervious surfaces?

Have road widths been minimized?

Have building setbacks been minimized to reduce driveway lengths?

Have parking ratios and needs been carefully examined?

Have needs and sizes of walkways been examined?

Minimum Disturbance

Has maximum total site area, including soils and vegetation, been protected from clearing and disturbance?

Are zones of undisturbed open space maximized?

Have buildings been sited carefully to reduce vegetation removal?

Can no-disturbance buffers be installed to limit zones of soil compaction?

Mitigative Practices

The Mitigative Practices include a tool box of options that promote groundwater recharge and improve water quality. These practices have been assigned to several groupings, although in many cases the practicesoverlap. Virtually all of these techniques make maximum use of vegetation and soil functions, so although they are all technically structures, they are of lower complexity and more rooted in natural process than conventional approaches.

Vegetated Swales

Vegetated swales are effective means of stormwater conveyance. At low slopes, they can recharge modest amounts of stormwater, filter it through vegetative processes, and slow it down.

Terraforming

Terraforming comes in a variety of techniques. These include constructing subtle berms along contour below undisturbed areas. The berms act as modest “dams” retaining the water for up-slope recharge. Also, subtle grading of depression areas promote retention and recharge throughout a site.

Level Spreading/Natural Areas

With a level spreader, stormwater spills over the lip of a long trench or berm, creating sheet flow across a broad area. The level spreaders slow down the intensity of runoff and discharge it over a large, adjoining vegetated area with good soils, which in turn filter it and assist in groundwater recharge. Filter strips are planted vegetated strips through which runoff passes that filter it and slow it down. Riparian buffers are vegetated zones along stream corridors that filter the stormwater passing through it and help minimize erosion. These techniques are most valuable when used in conjunction with preventive strategies that leave larger natural areas undisturbed in order to handle these additional stormwater inputs.

Bioretention/biofiltration

Bioretention is a popular name given to just about any type of device that utilizes vegetation and soil to manage stormwater flows. They can be subtle depressions that exist naturally and receive stormwater or depending on soil conditions, they may be physically constructed “pits” that are filled with permeable soils and planted with native vegetation that adapt to both wet and dry conditions. These systems can either be “on-line” (part of the stormwater conveyance flow) or “off-line” (separate from the rest of the stormwater management/mitigation system). In either case, they have modest ponding storage that is recharged over the course of time.

Other mitigative devices

Not all of the required volume storage to meet peak rate requirements for a given site may be attained through the practices outlined above. At times, it may be necessary to put in “structural” systems such as in-ground infiltration trenches, infiltration pipes, or stormwater wetlands. However, these systems should be explored only after both Preventive Approaches and Mitigative Practices of Conservation Design have been maximized to the greatest extent possible.

Conclusion

The Conservation Design Procedure is perhaps best characterized as a “check list” or protocol of questioning during the site design process. The key to this approach is its range of innovative, yet effective options, not afforded in conventional systems which tend to be standardized irrespective of the particular site. With Conservation Design, the approaches and practices can be combined in a variety of ways to minimize the impacts of development on the water cycle and still meet regulatory stormwater management criteria such as peak rate control. Often, because these approaches and practices tend to favor multiple objectives and nonstructural techniques, Conservation Design can be less expensive to install and maintain than conventional systems. Also, because they are largely based on soil and vegetative processes, conservation design techniques tend to improve in function overtime, while conventional detention basin systems tend to diminish in function over time. In terms of water quality, Conservation Design Approaches and Practices can outperform conventional systems. For example, filter strips and biofiltration areas can remove over 90% of the suspended solids, 40% of the phosphorous, and 20% of the nitrates (Dillaha et al. 1986 and 1989; Yu et al. 1993). In addition, reduced yard areas and increased forested zones prevent chemical runoff from lawns-a great contributor to non-point source pollution-at the outset.

Conservation Design is limited only by the creativity of the designer and the flexibility of the developer and regulatory agencies. It must be emphasized that the Conservation Design approach will not eliminate a need for structural systems in all cases; however, more often than not, Conservation Design can replace or reduce the need for structural practices while providing attractive site amenities. And in the process, the water cycle will be balanced, and forests and other sensitive resources will be preserved. In short, Conservation Design can do more with less, and more for less, than conventional approaches to stormwater management.

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Low–Impact Development Design: A New Paradigm for Stormwater Management Mimicking and Restoring the Natural Hydrologic Regime An Alternative Stormwater Management Technology

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Abstract

Whether complying with federal or state regulations or addressing local vital watershed protection/restoration objectives, local jurisdictions are confronted with the daunting task of developing, administering and funding complex effective multi-objective stormwater management programs, Today's comprehensive stormwater program not only has to deal with runoff quantity and quality control but, may also have to address such complicated issues as ecosystem restoration, combined sewer overflow reduction, fisheries protection, potable surface/ground water source protection, and wetland, riparian buffer and stream protection. As our understanding of the technical and practical limitations of conventional stormwater management technology has increased over the past two decades, and as watershed protection objectives have changed, many jurisdictions have begun to question the efficacy and cost-effectiveness of conventional stormwater approaches in meeting today's complex environmental/water resources objectives. Older communities with existing extensive stormwater management infrastructures are also struggling with the economic reality of funding the high costs of maintenance, inspection, enforcement and public outreach necessary to support an expanding and aging infrastructure. Still more challenging are the exceptionally high costs of retrofitting existing urban development using conventional stormwater management end-of-pipe practices to restore and protect receiving waters and living resources.

With growing concerns about the limitations of conventional technology and to address the changing objectives of watershed protection, in 1990 Prince George's County's Department of Environmental Resources (PGDER) began exploring alternative stormwater management practices and strategies. The development of bioretention or "Rain Gardens" (using the green space to manage runoff within small depressed landscaped areas) led to an understanding of how to optimize and engineer the landscape to restore hydrologic functions by uniformly integrating micro-scale management practices and impact-minimization measures into the development landscape. In 1997 PGDER released the Low Impact Development (LID) Design Manual demonstrating the principles and practices of LID to create a hydrologically functional landscape (PGDER, 1997).

LID stormwater management technology can maintain or restore a watershed's hydrologic regime by fundamentally changing conventional site design to create an environmentally and hydrologically functional landscape that mimics natural hydrologic functions (volume, frequency, recharge and discharge). This is accomplished in four ways. First: minimizing impacts to the extent practicable by reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, and reducing the use of pipes and minimizing clearing/grading. Second: recreating detention and retention storage dispersed and evenly distributed throughout a site with the use of open swales, flatter slopes, depression storage, rain gardens (bioretention), water use (rain barrels), etc. Third: maintaining the predevelopment "time of concentration" by strategically routing flows to maintain travel time. Fourth: providing effective public education and socioeconomic incentives to ensure property owners use effective pollution prevention measures and maintain management measures. With LID, every site feature is multifunctional (green space, landscaping, grading, streetscapes, roads and parking lots) and helps to reduce stormwater impacts or provide/maintain beneficial hydrologic functions. The cumulative beneficial impact of using the wide array of distributed LID techniques allows the site designer to maintain or restore watershed's natural relationship between rainfall, runoff, infiltration and evaporation.

The effective use of LID site design techniques can significantly reduce the cost of providing stormwater management. Savings are achieved by eliminating the use of stormwater management ponds, using less pipe, inlet structures, curbs

and gutters, less roadway paving, less grading and clearing. Where LID techniques are applicable, and depending on the type of development and site constraints, stormwater and site development design construction and maintenance costs can be reduced by 25 % to 30% compared to conventional approaches.

The creation of LID's wide array of micro-scale management principles and practices has led to the development of new tools to retrofit existing urban development. Micro-scale management practices that filter, retain and detain runoff can be easily integrated into the existing green space and streetscapes as part of the routine maintenance and repair of urban infrastructure. LID retrofit techniques may lead to drastic reductions in the cost of retrofitting existing urban development. Reducing urban retrofit costs will increase the ability of cities to implement effective retrofit programs to reduce the frequency and improve the quality of CSOs and improve the quality of urban runoff to protect receiving waters. LID represents a radically different approach to controlling stormwater runoff that provides effective tools to restore or maintain a watershed's hydrologic functions for new or existing development.

In 1998 EPA provided grant funding to assist PGDER in their efforts to develop a general manual describing LID principles and practices, and share this technology with other local governments throughout the nation. Efforts are currently underway with EPA to further advance LID technology by improving the sensitivity of current hydrology and hydraulic analytical models for application with small watersheds and sites and to develop new micro-scale control approaches and practices for urban retrofit. Additional efforts are also underway to demonstrate how LID micro-scale management and multifunctional infrastructure principles and practices can be used to control highway runoff within existing rights-of-way. It is hoped that the LID national manual will help to stimulate debate on the state of current stormwater, watershed protection and restoration technology and its future direction. The lessons learned about LID planning, principles, practices and research are described in detail in the reference documents listed at the end of this paper. Copies of these reference documents can be obtained by calling the Prince George's County's Department of Environmental Resources at (301) 883-5832.

Background

Typically, adverse stormwater impacts are mitigated through conservation of natural resources (forests, streams, floodplains and wetlands); zoning restrictions to direct densities and increase open space; and the use of structural or non-structural control technologies (best management practices - BMP's) to treat and manage runoff quantity and quality. Many conventional stormwater mitigation approaches, such as management ponds, exhibit a number of inherent practical, environmental and economic limitations including inability to replicate predevelopment watershed hydrology, elevated water temperatures, costly maintenance burdens, and accelerated stream erosion due to the increased duration and frequency of runoff events. Furthermore, because current mitigation practices only lessen development impacts, there is concern about the cumulative impacts of the widespread use of conventional mitigation practices that may fundamentally alter a watershed's hydrologic regime and water quality, adversely affecting receiving waters and the integrity of their ecosystems. Many highly urbanized jurisdictions are beginning to question the efficacy of current technology and are finding it harder to ensure, enforce or fund stormwater programs and maintain the massive infrastructure created by conventional approaches.

Currently every site is designed with one basic overriding goal - to achieve good drainage. As we develop a site reshaping the landscape inch by inch, its hydrologicfunctionsare altered on a micro-scale level. The cumulative impacts of micro-scale changes to the landscape drastically alter watershed hydrology. If sites can be designed to achieve good drainage, destroying natural hydrologic functions, why not design sites with the opposite objective to maintain predevelopment hydrologic functions? If inch by inch, sites are carefully and intelligently engineered to maintain hydrologic functions, would the cumulative beneficial affects result in the preservation of a watershed's hydrology? Can a site be designed in a way to remain as a functional part of a watershed's hydrological regime? To achieve a hydrologically functional development there must be a radical change in our thinking. We must not think in terms of impact mitigation as the stormwater management objective, but rather preservation of hydrologic and environmental functions. We should design sites to maintain hydrologic functions not just to mitigate impacts. Can our current stormwater management technology adequately meet our regulatory objectives and water resources/ecosystem protection needs? No one can answer that question for sure. However, it has not been shown that conventional ponds replicate predevelopment hydrology nor is there any evidence to suggest that conventional technology can ensure the ecological integrity of ecosystems. In fact, recent studies suggest that conventional approaches can not meet our water/natural resources and ecological objectives.

Introduction

With growing concerns about the economicsand efficacy of conventional technology, in 1990 Prince George's County Maryland's Department of Environmental Resources began exploring alternative stormwater management practices. The success that was achieved through the development and use of bioretention (filtering or infiltration runoff in small depressed landscaped areas) led us to understand that perhaps changing the form and function of the developed landscape could be important in mitigating urban stormwater impacts. Later it was realized that through intelligent site design and uniform distribution of LID micro-scale management controls it was possible to maintain or restore hydrologic functions in a developed watershed. What is not known is how much of a watershed's hydrologic functions can be maintained or restored within a given development type (residential, commercial or industrial)? The one limiting factor to maintaining/restoring the hydrologic regime for highly urbanized development is the lack of available micro-management tools. Much of the current research underway is to expand the number of practices applicable in highly urbanized areas.

LID's objective is to preserve the natural predevelopment hydrologic regime. If predevelopment hydrology and water quality can be maintained, this would provide the best level of protection possible to receiving waters and aquatic living resources. Experience over the last 20 years has demonstrated that maximizing the efficiency of conventional conservation measures and the use of conventional end-of-pipe stormwater management practices can not reasonably be used to restore watershed functions. What is needed is a new philosophical approach to site development, an approach that will allow the designer to retain a site's hydrologic functions.

The approach used in LID designs is really an old one. LID borrows its basic principles from nature - uniform distribution of micro-management controls. In a natural setting, stormwater is controlled by a variety of mechanisms (interception by vegetation, small depression storage, channel storage, infiltration and evaporation) uniformly distributed throughout the landscape. LID mimics these mechanisms by uniformly distributing small infiltration, storage, and retention and detention measures throughout the developed landscape. What we soon began to see is that every development feature (green space, landscaping, grading, streetscapes, roads, and parking lots) can be designed to provide some type of beneficial hydrologic function.

Low - Impact Development General

LID controls stormwater at the source creating a hydrologically functional landscape that mimics natural watershed hydrology. Low impact development (LID) achieves stormwater management controls by fundamentally changing conventional site design to create an environmentally functional landscape that mimics natural watershed hydrologic functions (volume, frequency, recharge and discharge). LID uses four basic management planning and design principles. First: minimize impacts to the extent practicable by reducing imperviousness, conserving natural resources/ecosystems, maintaining natural drainage courses, reducing use of pipes and minimizing clearing and grading. Second: provide runoff storage measures dispersed uniformly throughout the landscape with the use of a variety of small decentralized detention, retention and runoff practices such as bioretention, open swales and flatter grades. Third: maintain the predevelopment time of concentration by strategically routing flows to maintain travel time and control discharge. Fourth: implement effective public education and incentive programs to encourage property owners to use pollution prevention measures and maintain on-lot landscape management practices. A developed site can be designed to become a hydrologically functional part of the watershed with comprehensive and intelligent use of LID practices and principles.

LID Basic Site Planning Strategies

The goal of LID is to design the site in a way that mimics hydrologic functions. The first step is to minimize the generation of runoff (reduce the change in the runoff curve number (CN)). In many respects, this step is very similar to traditional techniques of maximizing natural resource conservation, limiting disturbance and reducing impervious areas. The major difference with LID is you must carefully consider how best to make use of the hydrologic soil groups and site topography to help reduce and control runoff. These considerations would include how to:

1. maintain natural drainage patterns, topography and depressions,
2. preserve as much existing vegetation as possible in pervious soils; hydrologic soil groups A and B,
3. locate **BMP's** in pervious soils; hydrologic soil groups A and B,
4. where feasible construct impervious areas on less pervious soil groups C and D,
5. disconnect impervious surfaces,
6. direct and disburse runoff to soil groups A and B,
7. flatten slopes within cleared areas to facilitate on-lot storage and infiltration and
8. re-vegetate cleared and graded areas.

Where ground water recharge is particularly important (to protect well, spring, stream and wetland flows) it is important to understand the source and mechanisms for ground water recharge. When using the LID design concepts to mimic the hydrologic regime you must determine how and where ground water on the site is recharged and where necessary, protect and utilize the recharge areas in the site.

LID Hydrologic Analysis/Response

The objective of LID site design is to minimize, detain and retain the post development runoff volumes uniformly throughout the site close to the source to simulate predevelopment hydrologic functions. Widespread use and uniform dispersion of on-lot small retention and/or detention practices to control both runoff discharge volume and rate is key to better replicating predevelopment hydrology. Using LID practices also produces runoff frequencies that are much closer to existing conditions than can be achieved by typical application of conventional **BMP's.** Management of both runoff volume and peak runoff rate is included in the design. This is in contrast to conventional end-of-pipe treatment that completely alters the watershed hydrology regime.

The LID site analysis and design approach focuses on four major hydrologically based planning elements. These fundamental factors affect hydrologic and are introduced below.

1. Curve Number (CN) **-** A factor that accounts for the effects of soils and land cover on amount of runoff generated. Minimizing the change in the post development CN by reducing impervious areas and preserving more trees and meadows to reduce runoff storage requirements, all to maintain the predevelopment runoff volume.

2. Time of Concentration (Tc) **-** This is related to the time runoff travels through the watershed. Maintaining the predevelopment Tc reduces peak runoff rates after development by lengthening flow paths and reducing the use of pipe conveyance systems.

3. Permanent storage areas (Retention) **-** Retention storage is needed for volume and peak control, water quality control and to maintain the same CN as the predevelopment condition.

4. Temporary storage areas (Detention) **-** Detention storage may be needed to maintain the peak runoff rate and/or prevent flooding.

Minimizing the Change in CN

Reducing the change in CN will reduce both the post development peak discharge rate and volume. Calculation of the LID CN is based on a detailed evaluation of the existing and proposed land cover so that an accurate representation of the potential for runoff can be obtained. This calculation requires the engineer/planner to investigate the following key parameters associated with LID including:

1. land cover type,
2. percentage of and connectivity of impervious cover,
3. hydrologic soils group (HSG), and
4. hydrologic conditions (average moisture or runoff conditions).

The following are some of the LID site planning practices that can be utilized to achieve a substantial reduction in the change of the calculated CN:

1. narrower driveways and roads (minimizing impervious areas),
2. maximized tree preservation and/or afforestation,
3. site finger-printing (carefully siting lots/roadways to avoid disturbance of streams, wetlands and other resources), greater use of open drainage swales,
4. preservation of soils with high infiltration rates to reduce CN,
5. location of BMP's on high-infiltration soils and,
6. construction of impervious features on soils with low infiltration rates.

Maintaining the Predevelopment Time of Concentration Tc

The LID hydrologic evaluation requires that the post development Tc be close to the predevelopment Tc. Minimizing the change in pre and post Tc will help maintain the same frequency of runoff discharges, assuming there is uniform distributed micro-scale retention and detention of LID practices. The following are some of the site planning techniques can be used to maintain the existing Tc:

1. maintain predevelopment flow path length by dispersing and redirecting flows using open swales and vegetated drainage patterns,
2. increase surface roughness (e.g., preserving woodlands, vegetated swales),
3. detain flows (e.g., open swales, rain gardens, rain barrels etc.),
4. minimize disturbances (minimizing soil compaction and changes to existing vegetation /drainage patterns),
5. flatten grades in impacted areas,
6. disconnect impervious areas (e.g., eliminating curb/gutter and redirecting down spouts) and,
7. connect pervious areas to vegetated areas (e.g., reforestation, afforestation).

The combined use of all these techniques results in cumulative impacts that modify runoff characteristics to effectively shift the post development peak runoff time and frequencies to that of the predevelopment condition, and lower the peak runoff rate.

Maintaining the Redevelopment Curve Number and Runoff Volume

Once the post development Tc is maintained at the predevelopment conditions and the impact of CN is minimized, any additional reductions in runoff volume must be accomplished through distributed micro-scale on-site stormwater management techniques. The goal is to select the appropriate combination of management techniques that simulate the hydrologic functions of the predevelopment condition to maintain the existing CN and corresponding runoff volume. The target design volume is equal to the initial abstraction of rainfall that would have occurred in the predevelopment condition.

LID site designs maximize the use of small retention practices distributed throughout the site at the source to provide the required volume storage. The required storage volume will be reduced when the change in the pre and post CN is minimized.

Retention storage allows for a reduction in the post development volume and the peak runoff rate. The increased storage and infiltration capacity of retention LID BMP's allow the predevelopment volume to be maintained. The most appropriate retention BMP's include:

1. bioretention cells (rain gardens),
2. infiltration trenches,
3. water use storage (rain barrels and gray water uses) and,
4. roof top storage.

Other possible retention BMP's include retention ponds, cisterns and irrigation ponds but it may be difficult to distribute these types of controls throughout a development site.

As retention storage volume is increased there is a corresponding decrease in the peak runoff rate, in addition to runoff volume reduction. If a sufficient amount of runoff is stored, the peak runoff rate may be reduced to a level at or below the predevelopment runoff rate. This storage may be all that is necessary to control the peak runoff rate when there is a small change in CN. However, when there is a large change in CN, it may be less practical to achieve flow control using volume control only.

Potential Requirement for Additional Detention Storage

In cases where very large changes in CN cannot be avoided, retention storage practices alone may be either insufficient to maintain the predevelopment runoff volume or peakdischarge rates or require too much space to represent a viable solution. In these cases, additional detention storage will be needed to maintain the predevelopment peak runoff rates. A number of traditional detention storage techniques are available that can be integrated into the site planning and design process for a LID site. These techniques include:

1. swales with check dams, restricted drainage pipes, and inlet/entrance controls,
2. wide, low gradient swales,
3. rain barrels/cisterns,
4. rooftop storage and
5. shallow parking lot/road storage.

Determination of Design Storm Event

The hydrologic approach of LID is to retain the same amount of rainfall within the development site as was retained prior to any development (e.g., woods or meadow in good condition) and then release runoff as the woods or meadow would have. By doing so, it is possible to mimic, to the greatest extent practical, the predevelopment hydrologic regime to maximize protection of receiving waters, aquatic ecosystems and ground water recharge. This approach allows the determination of a design storm volume that is tailored to the unique soils, vegetation and topographic characteristics of the watershed. This approach is particularly important in watersheds that are critical for ground water recharge to protect stream/wetland base flow and ground or surface water supplies.

LID BMP's

Site design techniques and BMP's can be organized into three major categories as follows; 1) runoff prevention measures designed to minimize impacts and changes in predevelopment CN and Tc, 2) retention facilities that store runoff for infiltration, exfiltration or evaporation and 3) detention facilities that temporarily store runoff and release through a measured outlet. Table 1, below, lists some of a wide array of LID BMP's and their primary functions. Placing these BMP's in series and uniformly dispersing them throughout the site provides the maximum benefits for hydrologic controls.

Table 1. Examples of LID BMP's and Primary Functions

BMP	Runoff Prevention	Detention	Retention	Conveyance	Water Quality
Bioretention		X	X		X
Infiltration Trench			X		X
Dry Wells		X	X		
Roof Top Storage		X	X		X
Vegetative Filter Strips				X	X
Rain Barrels		X	X		
Swale and Small Culverts		X		X	X
Swales		X		X	X
Infiltration Swale		X	X	X	X
Reduce Imperviousness	X				
Strategic Clearing / Grading	X				
Engineered Landscape	X				
Eliminate Curb and Gutter	X				X
Vegetative Buffers	X				X

Water Quality

LID maximizes the use of the developed landscape to treat stormwater runoff. Not only can the landscape be used to store, infiltrate and detain runoff, the unique physical, chemical and biological pollutant removal/ transformation/immobilization/detoxification capabilities of the soil, soil microbes and plants can be used to remove pollutants from runoff. For example, bioretention basins or rain gardens are designed to use the upland soil/microbe/plant complex to remove pollutants from runoff. Rain gardens which look and function like any other garden except they treat runoff are designed with a layer of 2-3 inches of mulch, 2-3 feet of planting soil and vegetation (trees shrubs and flowers). Figure 1 shows a parking lot landscape island rain garden (bioretention practice) that uses a high rate filter media with plants to filter and treat 90% of the annual volume of runoff from the parking lot.

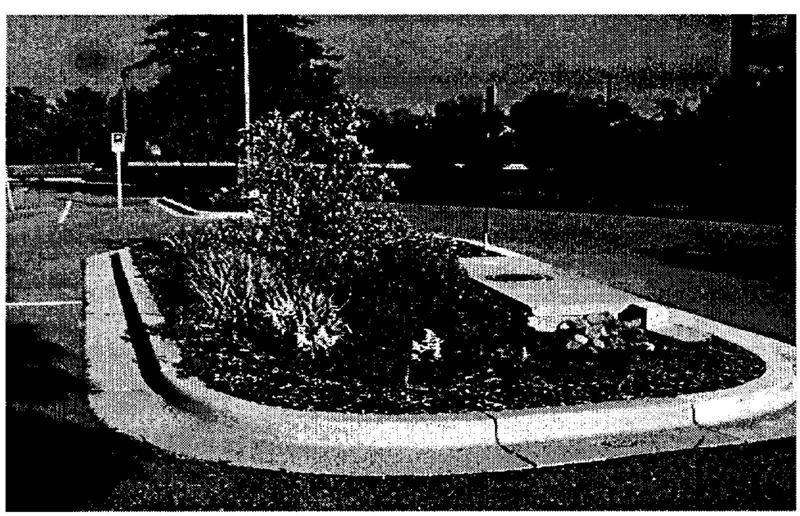

Figure 1. Parking Lot Rain Garden.

Studies conducted by the University of Maryland have shown rain gardens to be very effective in removing pollutants. The percent pollutant removal of various contaminants is shown below in Table 2. The results shown represent the average removal rates under a wide variety of flow rates and pollutant concentrations.

Table 2. Percent Pollutant Removal by Rain Gardens

cu	Pb	Zn	P	TKN	NH4+	NO3-	TN*
%	%	%	%	%	%	%	%
93	99	99	81	68	79	23	43

. Removal varied as a function of depth in the soil. Percent removal shown is at a depth of approximately 3 feet.
Testing Conducted by the University of Maryland, Department of Engineering

The variety of physical, chemical and biological pollutant removal mechanisms available in the complex rain garden system is staggering. A description or explanation in any detail of these mechanisms is beyond the scope of this paper. A more detailed description can be found in the 1998 "Optimization of Bioretention Design" study conducted by the University of Maryland. Mulch has been found to be very effective in removing heavy metals through organic complexing with the hydroxyl and carboxyl sites on the organic molecules. Soil bacteria can metabolize (use as a carbon energy source) oil, grease and gasoline into CO2 and water in the presence of adequate nutrients and oxygen. Soil bacteria have been used for years for the remediation of contaminated soils. Plants are known to uptake, transpire, accumulate and detoxify heavy metals and many other toxic compounds. The physiologic and metabolic processes of plants are used to clean contaminated soils through phytoremediation. A goal of LID is to maximize the use of upland landscape with its soil/ microbes/ plant complex to treat runoff. Using upland systems to trap and remove pollutants allows one to more easily control the fate of contaminants and prevent them from entering the water column where they are almost impossible to contain and remove.

Public Outreach and Pollution Prevention

Pollution prevention and maintenance of on-lot LID BMP's are two key elements in a comprehensive approach. Effective pollution prevention measures can reduce the introduction of pollutants to the environment and extend the life of LID treatment BMP's. Public education is essential to successful pollution prevention and BMP maintenance. Not only will effective public education complement and enhance BMP effectiveness, it can also be used as a marketing tool to attract environmentally conscious buyers, promote citizen stewardship, awareness and participation in environmental protection programs and help to build a greater sense of community based on common environmental objectives and the unique character of LID designs.

Costs

LID case studies and pilot programs show that at least a 25% reduction in both site development and maintenance costs can be achieved by reducing grading and the use of pipes, ponds, curbs and paving. In one subdivision called Somerset which used the rain garden LID technique for water quality controls, the developer saved $4,500 per lot or a total of $900,000 by eliminating the need for curbs, ponds and drainage structures. Maintenance costs are also reduced in scale and magnitude by using the small LID practices. LID site designs require only routine landscape care and maintenance of the vegetation, This eliminates the high costs of pond maintenance associated with dam repairs and dredging.

Road Blocks to LID

In the development and acceptance of the LID site planning approach, a number of roadblocks had to be overcome. Regulating agencies, the development community and the public all had concerns about the use of new technology. The

LID design manual represents the culmination of four years of work to address all of these concerns and issues. Some of the major components of the LID approach, which addressed the many concerns, include:

1. develop an hydrologic analytical methodology to demonstrates the equivalence of LID to conventional approaches,

2. develop new road standards which allow for narrow roads, open drainage and cluster techniques,

3. streamline the review process for innovative LID designs which allow easy modification of site, subdivision, road and stormwater requirements,

4. develop a public education process which informs property owners on how to prevent pollution and maintain on lot BMP,

5. develop legal and educational mechanisms to ensure BMP's are maintained,

6. demonstrate the marketability of green development,

7. demonstrate the cost benefits of the LID approach,

8. provide training for regulators, consultants, public and political leaders and,

9. conduct research to demonstrate the effectiveness of bioretention BMP's.

Summary

LID is a viable economically sustainable alternative approach to stormwater management and the protection of natural resources. LID provides tangible incentives to a developer to save natural areas and reduce stormwater and roadway infrastructure costs. LID can achieve greater natural conservation by using conservation as a stormwater BMP to reduce the change in CN. As more natural areas are saved, less runoff is generated and stormwater management costs are reduced. This allows multiple use and benefits (environmental and economical) of the resource.

Additionally, developers have incentives to reduce infrastructure costs by reducing impervious areas, and eliminating curbs/gutters and stormwater ponds to achieve LID stormwater controls. Reduction of the infrastructure also reduces infrastructure maintenance burdens making LID designs more economically sustainable. Superior protection of aquatic and riparian ecosystems can be achieved since a LID developed watershed functions in a hydrologically similar manner as the predevelopment conditions. Recreating the predevelopment hydrological regime is a better way to protect the receiving waters than the conventional end-of-pipe mitigation approaches.

LID promotes public awareness, education and participation in environmental protection. As every property owner's landscape functions as part of the watershed, they must be educated on the benefits and the need for maintenance of the landscape and pollution prevention. LID developments can be designed in a very environmentally sensitive manner to protect streams, wetlands, forest habitat, save energy, etc. The unique character of a LID green development can create a greater sense of community pride based on environmental stewardship.

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A National Menu of BMPs for the Phase II NPDES Storm Water Program

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Introduction

Implementation of the Phase II NPDES Storm Water Program, which is presently "proposed," will be enhanced by the development of several tools used to help reduce discharges of pollutants from regulated small construction activities and from regulated small municipal separate storm sewer systems (MS4s). One of the tools being developed by EPA is a national menu of best management practices (BMPs), from which regulated Phase II municipalities can select as they develop their stormwater management programs.' The purpose of the national menu of BMPs is to provide a list of options available to regulated Phase II municipalities as they develop a stormwater programs. The national menu of BMPs may be adopted or modified by each NPDES permitting authority, or the permitting authority may develop its own menu of BMPs for use by the Phase II municipalities under its jurisdiction. This paper describes the process of developing the national menu of BMPs and measurable goals for each of the six minimum measures required to be in the stormwater management programs.

Process of Development

The process used in developing the menu was to first list appropriate BMPs for each minimum control measure, with subcategories under certain control measures.' Then, a basicformat for presenting the information about each BMP was established. Information being provided for each BMP in the menu consists of BMP name, description, an illustration, applicability and design considerations, limitations, operation and maintenance, effectiveness, cost, and references. The menu is being prepared by EPA, with support from Tetra Tech, Incorporated, and the Center for Watershed Protection. A peer involvement/peer review group has been selected and will provide review and input to the process of developing the menu over the course of the next year. The menu is currently being reviewed and developed as a traditional hard copy document. Following development, there are plans to make the menu available as an interactive Web-based tool. The menu of BMPs is scheduled to be released by October, 2000.

Descriptions of Six Minimum Control Measures, with Lists of BMPs

1) Public Education and Outreach

This measure in the proposed rule calls for the creation of a public education program to inform citizens about the impacts that stormwater runoff can have on water quality. It includes the preparation and distribution of educational materials to the community, describing these impacts and steps that can be taken to reduce pollution from discharges of stormwater. Examples of such steps include proper septic system maintenance, limitations on use and runoff of household and garden chemicals, proper disposal of used motor oil or household hazardous wastes, and involvement in local stream restoration activities. The following BMPs have been identified (in the Draft Rule) under four major subcategory groups in the menu for the Public Education and Outreach minimum measure:

Public outreach/education for homeowners

- Lawn and garden activities, including proper pesticide use and disposal practices

- Water conservation practices
- Proper disposal of used materials or household hazardous wastes
- Pet waste management

Targeting public outreach/education

- Education/outreach for commercial activities (parking lots, gas stations, etc.)
- Tailoring outreach programs to communities, including minority and disadvantaged, as well as children
- Classroom education on stormwater
- Distributing stormwater educational materials (how, to whom)

Public Outreach Programs for New Development

- Low-impact development (includes buyer awareness, legal documents, and settlement documents)

Pollution Prevention Programs for Existing Development

- Educational display, pamphlet, booklet, utility stuffer
- Using the media (includes newspaper, magazine, radio, television, public service announcements, and Internet messages)
- Promotional giveaway

2) Public Participation/Involvement

This measure in the proposed rule includes compliance with state and local public notice requirements, but goes beyond that to encourage municipalities to seek public involvement in the development and review of their stormwater programs. Opportunities for members of the public to participate in the development of their municipality's stormwater management program may include serving as citizen representatives on a local stormwater management panel, attending public hearings, working as citizen volunteers to educate others about the program, assisting in program coordination with other pre-existing programs, or participating in volunteer monitoring efforts. The following BMPs have been identified under two major subcategory groups of practices in the menu for the Public Participation/Involvement minimum measure:

Activities/Public Participation

- Storm drain stenciling
- Stream cleanup
- Volunteer monitoring
- Reforestation program
- Wetland plantings
- Adopt-A-Stream program

Involvement/Public Opinion

- Watershed organization

- Stakeholder meetings (includes local stormwater management ponds)
- Attitude surveys
- Community hotlines

3) Illicit Discharge Detection and Elimination

This measure envisions the creation of an illicit discharge detection and elimination program. Specific program elements include developing a demonstrated knowledge base of the MS4, using maps or other documents to identify major outfalls and pipe networks on a topographic basis; developing a plan to address illicit discharges into the MS4, including appropriate enforcement procedures to the extent allowable by law; and developing a process for informing the public about the hazards associated with illicit discharges and the improper disposal of waste. For example, recycling programs and other public outreach activities could be developed to address sources of illicit discharges, including used motor oil, antifreeze, pesticides, herbicides, and fertilizers. The following BMPs have been identified for the menu for the Illicit Discharge Detection and Elimination minimum measure:

- Failing septic systems
- Industrial connections
- Recreational sewage
- Sanitary sewer overflows
- Identifying illicit connections
- Wastewater connections to the storm drain system

4) Construction Runoff Control

This measure provides for the enforcement of a program to reduce pollutants in storm water runoff from construction activities resulting in the disturbance of one acre to five acres of land. The program would apply to the individuals responsible for activities at construction sites and should include an ordinance to control sediment and erosion; a mechanism to ensure control of other wastes at construction sites, such as discarded building materials, concrete truck washout, and sanitary waste that could impact water quality; requirements for the implementation of appropriate BMPs, such as silt fences, temporary detention ponds and hay bales; provisions for preconstruction review of site management plans; procedures for receipt and consideration of comments and other information provided by the public; regular inspections during construction; and penalties to ensure compliance. The following BMPs have been identified under 11 major subcategory groups of practices in the menu for the Construction Runoff Control minimum measure:

Minimize Clearing

- Land grading
- Permanent diversion
- Preservation of natural vegetation (includes tree preservation and protection)

Stabilize Exposed Soils

- Chemical stabilization
- Mulching

- Permanent seeding
- Sodding
- Soil roughening

Protect Steep Slopes

- Geotextiles
- Gradient terraces
- Soil retention (includes slope stabilization, retaining wall, reinforcement)
- Temporary slope drain (a.k.a. - pipe slope drain)
- Temporary storm drain diversion

Stabilize Drainage Ways

- Check dam (a.k.a. grade stabilization structure)
- Filter berm
- Grass-lined channel
- Riprap

Protect Waterways

- Temporary diversion
- Temporary stream crossing (bridge, culvert)
- Vegetated buffer

Phase Construction

- Construction sequencing
- Dust control

Install Perimeter Controls

- Temporary diversion dikes, earth dikes, and interceptor dikes (includes temporary fill diversions)
- Sand fence and wind fences
- Silt fence
- Brush barriers

Install Sediment Trapping Devices

- Sediment basin/rock dam
- Sediment filters and sediment chambers

- Sediment traps

Inlet Protection

- Stabilized construction entrances
- Storm drain inlet protection (includes block and gravel, excavated drop, fabric drop, and sod drop inlet protection)

Education and Awareness

- Contractor certification and inspector training
- BMP inspection and maintenance

5) Post-Construction Runoff Control

This measure uses post-construction controls as part of a program to address stormwater runoff from new development and redevelopment projects using appropriate structural and non-structural BMPs. Non-structural BMPs are preventive actions using management and source controls, such as policies and ordinances that result in protection of natural resources and prevention of runoff. Non-structural BMPs might include requirements that encourage growth in identified areas while protecting sensitive areas such as wetlands and riparian zones, minimizing impervious surfaces, maintaining open space, and minimizing clearing, grading, or other disturbance of soils and vegetation. Some of the typical structural BMPs include storage practices (wet ponds, extended-detention dry ponds, or other storage facilities with outlets); infiltration practices (infiltration basins, infiltration trenches, and porous pavement); and filtration practices (grassed swales, sand filters, and vegetated filter strips). This measure should also ensure effective and reliable performance by providing for the long-term operation and maintenance of the selected BMPs. The following BMPs have been identified under eight major subcategory groups of practices for the Post-Construction Runoff Control minimum measure:

Ponds

- Extended detention dry basin or pond (with or without permanent pools or shallow marshes near the outlet), includes tank storage
- Wet pond

Infiltration Practices

- Infiltration basin (a.k.a. - recharge basin)
- Infiltration trench (a.k.a. - infiltration galley)
- Porous pavement

Filtration Practices

- Bioretention
- Filters, including organic media filter (peat sand or compost-type), sand filter, multichamber treatment train (MCTT) system, and inlet filtration systems

Vegetative Practices

- Constructed wetland, shallow marsh
- Grassed swale

- Vegetative filter strip

Runoff Pretreatment Practices

- Catch basin
- In-line storage, includes flow regulator information
- Manufactured systems for water quality inlets

Experimental Practices

- Alum injection system

On-lot Treatment

- On-lot treatment includes information on dry wells, roof downspout systems, rain barrels, exfiltration storage systems, french drains, and dutch drains

Better Site Design

- Conservation easements
- Infrastructure planning
- Buffer zones/setbacks
- Open space development
- Narrow streets
- Curb elimination
- Green parking lot
- Alternative turn-around
- Urban forestry
- Alternative pavers

6) Pollution Prevention/Good Housekeeping

This measure in the proposed rule envisions the creation of an operation and maintenance/training program to prevent or reduce pollutant runoff from municipal operations. The program should include training for municipal staff to address prevention measures in government operations, such as park and open space maintenance, fleet maintenance, planning, building oversight and stormwater collection system maintenance. Other possible pollution prevention activities that might be relevant include controls for reducing or eliminating the discharge of pollutants from streets, roads, highways, municipal parking lots, maintenance and storage yards, and waste transfer stations; programs to promote recycling and pesticide use information; procedures for proper disposal of waste removed from municipal systems and public areas (such as streets) including dredge spoil, accumulated sediments, floatables, and other debris; and new flood management projects to assess the impacts on water quality and examine exiting projects to determine if they need additional water quality protection devices or practices. The following BMPs have been identified under two major subcategory groups of practices in the menu for the Pollution Prevention/Good Housekeeping minimum measure:

Source controls

- Animal waste collection
- Automobile maintenance
- Car washing
- Illegal dumping control
- Landscaping and lawn care
- Pest control
- Parking lot and street cleaning
- Roadway and bridge maintenance
- Septic system controls

Materials Management

- Alternative products
- Hazardous materials storage
- Household hazardous waste collection
- Road salt application and storage
- Spill response and prevention
- Used oil recycling

Conclusion

As part of the Stormwater Phase II Tool Box, the Menu of BMPs should help municipalities develop, implement, and enforce the Phase II program. The menu will be available in time for regulated municipalities to use in complying with stormwater management program requirements under Phase 2 permits and might also benefit other jurisdictions and individuals.

References

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Determining Urban Stormwater BMP Effectiveness

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Abstract

The overall purpose this US EPA funded cooperative research program with the American Society of Civil Engineers (ASCE) is to develop a more useful set of data on the effectiveness of individual best management practices (BMPs) used to reduce pollutant discharges from urban development. BMP performance data gathered at a particular site should not only be useful for that site, but also be useful for comparing studies of similar and different types of BMPs in other locations. Almost all BMP effectiveness studies in the past have provided very limited data that is useful for comparing BMP design and selection among individual BMP types (e.g. sand filters). This paper overviews some of the problems of past BMP effectiveness studies from the perspective of comparability between studies. It suggests some of the ways that data should be collected to make it more useful for assessing factors (such as settling characteristics of inflow solids and physical features of the BMP) that might have led to the performance levels achieved. It briefly presents the database that has been developed by this project, which not only serves as a tool for storing data from existing studies, but as a tool for entering and storing data collected from future studies. Discussed are considerations that affect data transferability, such as effectiveness estimations, statistical testing, etc. It overviews the efforts to establish and analyze the data base for existing studies and overviews proposed analyses for the future, when more studies that have followed the protocols are available. The database has specifically pointed out the need for additional BMP performance studies, as the current data is very sparse in terms of studies that have recorded enough information to be useful in assessing BMP type performance.

Introduction

Many studies have assessed the ability of stormwater treatment BMPs (e.g., wet ponds, grass swales, stormwater wetlands, sand filters, dry detention, etc.) to reduce pollutant concentrations and loadings in stormwater. However, in reviewing and summarizing the information gathered from these individual BMP evaluations, it is apparent that inconsistent study methods and reporting make wider-scale assessments difficult, if not impossible. For example, individual studies often included the analysis of different constituents and utilized different methods for data collection and analysis, as well as varying degrees of information on BMP design and inflow characteristics. Just the differences in monitoring strategies and data evaluation alone contribute significantly to the range of BMP "effectiveness"that has been reported. These differences make combining these individual studies almost impossible to assess what design factors may have contributed to the variation in performance (Strecker et al., 1992). Urbonas (1994 and 1995) and Strecker (1994) summarized information that should be recorded regarding the physical, climatic, and geological parameters that likely affect the performance of a BMP and considerations regarding sampling and analysis methods.

Efficiency, Effectivness, and Performance

In order to better clarify the terminology used to describe the level of treatment achieved and how well a device, system, or practice meets its goals, definitions of some terms often used loosely in the literature are provided here. These terms help to better specify the scope of monitoring studies and related analyses:

- Best Management Practice (BMP) -A device, practice, or method for removing, reducing, retarding, or preventing targeted stormwater runoff constituents, pollutants, and contaminants from reaching receiving waters

- BMP System - A BMP system includes the BMP and any related bypass or overflow. For example, the efficiency (see below) can be determined for an offline retention (Wet) Pond either by itself (as a BMP) or for the BMP system (BMP including bypass)

- Performance - measure of how well a BMP meets its goals for stormwater that is treated by the BMP

- Effectiveness - measure of how well a BMP system meets its goals in relation to all stormwater flows

- Efficiency - measure of how well a BMP or BMP system removes pollutants

The ASCE project team is working with available data to determine efficiency of BMPs and BMP systems. In addition, effectiveness and performance are being evaluated, acknowledging the limitations of existing information about the goals of specific BMP projects. Quantification of efficiency only evaluates a portion of the overall performance or effectiveness of a BMP or BMP system. Calculation of the efficiency helps to determine additional measures of performance and effectiveness, for example the ability of a BMP to meet any regulatory goals. A list of typical goals and the current ability of the ASCE/EPA project to help evaluate them is shown in Table 1.

Problem: BMP Performance Study Inconsistencies

Studies of BMP effectiveness have utilized significantly different:

- sample collection techniques (e.g., from sample collection types--grab, composite, etc., flow measurement techniques, to how the sample was cornposited, etc.);

- water quality constituents, including: chemical species, methods (detection limits), form (e.g., dissolved vs. total, vs. total recoverable, etc.), and treatment potential;

- data reporting on tributary watershed and BMP design characteristics (e.g., tributary area or watershed attributes such as percent impervious, land use categories, rainfall statistics, etc.);

- effectiveness estimation techniques (there are at least four common techniques that have been utilized to assess effectiveness that can cause significant differences in pollutant removal reporting, with the same set of data), and potential alternatives to reporting just concentration/loading reductions; and

- statistical validation of results (typical lack of statistical tests to determine if the reported removal efficiency can in fact be shown to be statistically different than zero).

Monitoring strategies that could be employed to monitor BMP effectiveness include:

- New BMP installation with new development- input/output (e.g., monitor new detention pond of newly developed watershed and evaluate inflow concentrations/loads vs. outflows) or conduct a “control” watershed comparison

- Retrofit of existing or new single BMP within existing watershed--input/output, and/or, before/after (e.g., retrofit of an existing flood control basin for water quality)

- Watershed-wide new structural or non-structural--“control” watershed comparison (e.g., new BMP catch basins in developing area)

- Watershed-wide structural retrofit or application of non-structural - before/after, and/or, “control” watershed comparison (e.g., catch basin retrofit on watershed scale)

Input/output monitoring is the typical approach utilized. However, control watersheds and before/after approaches have also been employed. All of the other potential factors that could be contributing to differences in performance must identified and accounted. On the other hand, it is beneficial to be able to show that a watershed-wide difference is or is

Table 1. Goals of BMP Projects and the Ability of the National Stormwater BMP Database to Provide Information Useful for Determining Performance and Effectiveness

Goals of BMP Projects Category		Ability to Evaluate Performance and Effective
Hydraulics	*Improve flow characteristics upstream and/or downstream of BMP	
Hydrology	‘Flood mitigation, improve runoff characteristics (peak shaving)	✓
Water Quality (Efficiency)	*Reduce downstream pollutant loads and concentrations of pollutants	✓
	‘Improve/minimize downstream temperature impact	✓
	*Removal of litter and debris	✓[1]
Toxicity	*Reduce acute toxicity of runoff	✓[1]
	*Reduce chronic toxicity of runoff	✓[1]
Regulatory	*Compliance with NPDES permit	
	*Meet local, state, or federal water quality criteria	✓[2]
Implementation Feasibility	*For non-structural **BMPs,** ability to function within management and oversight structure	
Cost	*Capital, operation, and maintenance costs	✓[1]
Aesthetic *Improve appearance of site	-	
Maintenance	*Operate within maintenance, and repair schedule and requirements	✓[1]
	*Ability of system to be retrofit, modified or expanded	✓
● Uangg* functionality	-	
Resources	‘Improve downstream aquatic environment/erosion control	-
	*Improve wildlife habitat	-
	*Multiple use functionality	-
Safety, Risk and Liability	*Function without significant risk or liability	
	*Ability to function with minimal environmental risk downstream	
Public Perception	‘Information is available to clarify public understanding of runoff quality, quantity and impacts on receiving waters	✓

✓ can be evaluated using the **ASCE/EPA** Database as information source
✓[1] will be able to be evaluated using the database as primary source of information after enough studies have been submitted
✓[2] can be evaluated using the database the primary source of information combined with a secondary source of comparative data

not being detected with BMP implementation. These differences in monitoring approach certainly effect the ability to compare studies.

Any of the above topics would require an in-depth discussion beyond the scope of this paper. Therefore, this paper will present only a brief overview of each and some potential solutions for improving how data is collected. The ASCE project team has developed a set of protocols and a database on BMP performance studies with the purpose of improving the consistency of BMP monitoring information. The project includes:

- Developing protocols for BMP monitoring and reporting
- Developing a database on BMP performance studies
- Conducting an evaluation of existing information to assist EPA in providing guidance to the regulated community

The database specifies a chosen set of reporting information, but does not guide users on how to develop such information. For example, it does not specify in detail what a flow-weighted composite sample is and how it should be collected. The next step beyond the EPA protocols and database effort should be a guidance document on monitoring data collection strategies and techniques to improve their consistency and ultimate transferability. A few of the issues related to proper guidance are discussed in the next two sections. It should be recognized that, with the development of the database and the protocols, it will be a number of years (5 to 10) before a significant number of new studies on BMPs are conducted utilizing the protocols. Therefore, a rigorous evaluation of BMP selection and design factors will need to take place in the long-term future.

Recommended Parameters for Assessing BMP Performance

In developing a method for quantifying BMP performance, it is helpful to look at the objectives of previous studies seeking such a goal. BMP performance studies usually are conducted to obtain information regarding one or more of the following objectives:

- What degree of pollution control does the BMP provide under typical operating conditions?
- How does performance vary from pollutant to pollutant?
- How does performance vary with various input concentrations?
- How does performance vary with large or small storm events?
- How does performance vary with rainfall intensity?
- How do design variables affect performance?
- How does performance vary with different operational and/or maintenance approaches?
- Does performance improve, decay, or remain the stable over time?
- How does the BMP's performance compare relative to other BMPs?
- Does the BMP reduce toxicity to acceptable levels?
- Does the BMP cause an improvement in downstream biotic communities?
- Does the BMP have potential downstream negative impacts?

The monitoring efforts implemented most typically seek to answer a subset of the above questions. This often leaves larger questions about the performance of the BMP, and the relationship between design and performance, unanswered. Standardization of BMP data collection and evaluation methods (i.e., guidance and the ASCE/EPA database) allows this broader set of questions to be examined.

There has been a very wide variety of pollutants analyzed in BMP and characterization studies. The protocols established under the EPA-funded cooperative research program recommend a standard set of constituents for BMP testing programs. Table 2 presents the recommended constituents developed from the review of previous studies with an understanding of costs and likelihood of providing meaningful results. A discussion of how these constituents were selected and a detailed description of each can be found in Strecker (1994).

There are some practical and technical considerations regarding data reporting which would facilitate data usefulness, including consistent formatting of data, the clear indication of QA/QC results, standard comparisons to water quality criteria, reporting of tributary watershed characteristics, and BMP design information. The last two items are considered critical for evaluation of what contributed to BMP effectiveness in one location over another.

Data Reporting. It is recommended that all constituent concentration data be reported as event mean concentrations (EMCs). These statistics should be based on use of the lognormal distribution. The NURP and FHWA studies (EPA,

Table 2. Recommended Standard Analytical Tests for Urban Stormwater BMP Assessment

Lab Analysis	EPA Method Number	Detection Limit (mg/l)
Conventional		
TSS	EPA 160.2	1
TDS	EPA 160.1	1
TOC	EPA 415.1	3
COD	EPA 410.4	1
Total Hardness	SM 314-A	1
Nutrients		
(NH^3 - N)	SM 417-AD	0.1
Total phosphorus (as P)	SM 424-CE	0.005
Ortho-phosphate (as P)	SM 424-E	0.05
Nitrate + nitrite (NO, + NO^2 - N)	EPA 353.1 or .2	0.05
Total Metals		
Cd (cadmium)	EPA 7131	0.0002
Pb (lead)	EPA 7421	0.0003
Cu (copper)	EPA 6010	0.001
Zn (zinc)	EPA 6010	0.001
Dissolved Metals		
Cd (cadmium)	EPA 7131	0.0002
Pb (lead	EPA 7421	0.0003
Cu (copper)	EPA 6010	0.001
Zn (zinc)	EPA 6010	0.001

1983a; Driscoll et al., 1990) identified that the lognormal distribution is suitable for characterizing EMC distributions. The high degree of variability is why proper statistical techniques should be employed to evaluate whether a measured difference between BMP before/after or input/output is significant. The recommended inclusion of outlet data as a part of any paper or report will allow comparisons of typical outlet concentrations and may allow the determination of the lowest or average expected concentration from a particular type of BMP. For example, it may be that wet ponds may only be able to treat to some minimum concentration range at the outlet and the "effectiveness" is greatly impacted by the inlet concentrations.

Quality Assurance/Quality Control (QA/QC). All monitoring studies should include a QA/QC program. The details and results of the QA/QC program should be reported in monitoring study reports and summarized in papers. It is especially important to discuss when data are characterized as estimates due to QA/QC results and when detection limits were affected. Too often this information is not included.

Comparisons to *Water Quality Criteria.* A method to gage effectiveness could be to monitor how the BMP affects the number of times (frequency) that EPA water quality criteria are exceeded in both the inflow and the outflow, to assess how the BMP reduces (or does not reduce) the frequency of potentially toxic events. For heavy metals analyses, it is recommended that hardness be collected for all storms monitored and that comparisons to criteria be made utilizing the dissolved fraction with the computed aquatic criteria as modified by EPA (1993b).

Watershed and BMP Design Parameters. Table 3 presents a summary of these parameters. These parameters (more detailed parameter lists are available on ASCE's Web page at http://www.asce.org/peta/tech/ nsbd01.html) have been selected with the purpose of being able to utilize this information to evaluate what BMP design attributes and tributary watershed characteristics can be linked to BMP effectiveness information.

The primary goals of the ASCE/EPA database development process were to facilitate efficient data entry, provide useful queries of stored data, and output information in a comprehensive and applicable manner through a user-friendly interface. The database was written in Microsoft@ Access incorporating Access relational database engine and features and the Visual Basic® for Applications programming language for customization of the functional aspects of the front end. Distribution will take place initially as an Access run-time version on CD-ROM, but will be available in the nearfuture over the Internet.

Table 3. Parameters to Report with Water Quality Data for Various BMPs

Parameter Type	Parameter	Retention (Wet) Pond	Extended Detention (Dry) Basin	Wetland Pond Basin	Grass Swale/ Wetland Channel	Sand/Leaf Compost Filter	Oil & Sand Trap/ Hydro-dynamic Device	Infiltration and Perc..
ibutary atershed	Tributary watershed area, average slope, average runoff coefficient, length, soil types, vegetation types	•	•	•	•	•	•	•
	Total tributary watershed impervious percentage and percent hydraulically connected	•	•	•	•	•	•	•
	Details about gutter, swer, swale, ditches, parking, roads in watershed	•	•	•	•	•	•	•
	Land use types (res., comm., ind., open) and acreage	•	•	•	•	•	•	•
eneral ydrology	Date and start/stop times for monitored storms	•	•	•	•	•	•	•
	Runoff volumes for monitored storms	•	•	•	•	•	•	•
	Peak 1 -hr intensity	•	•	•	•	•	•	•
	Design storm/flood recurrence intervals and magnitude	•	•	•	•	•	•	•
	Peak flow rate, depth, and Manning's roughness coefficient for the 2-year storm				•			
	Depth to seasonal high groundwater/impermeable layer		•		•			•
	Saturated hydraulic conductivity, infiltration rate, soil group				•			•
	Average annual values for number of storms, precipitation, snowfall, min./max. Temp., from appropriate weather station	•	•	•	•	•	•	•
later	Alkalinity, hardness and pH for each monitored storm	•	•	•	•	•	•	•
	Water temperature	•	•	•	•	•	•	•
	Sediment settling velocity distribution, when available	•	•	•	•	•	•	•
	Facility on- or off-line?	•	•	•	•	•	•	•
	Bypassed flows during events	•	•	•	•	•	•	•

eneral rcility	Type and frequency of maintenance	•	•	•	•	•	•	•
	Types and location of monitoring instruments	•	•	•	•	•	•	•
	nlet and outlet dimensions, details, and number	•	•	•	•	•	•	•
	Wedia or granular material depth, type, storage volume, and porosity					•		•
'et Pool	Volume of permanent pool	•		•		•	•	
	Length of permanent pool	•		•		•	•	
	Permanent pool surface area	•		•		•	•	
	Littoral zone surface area	•						
	Solar radiation, days of sunshine, wind speed, pan evaporation, from appropriate weather station	•	•	•	•			•
etention olume	Detention (or surcharge) and flood control volumes	•	•	•		•	•	•
	Detention basin's surface area and length	•	•	•		•	•	•
	3rimful and half-brimful emptying time	•	•	•		•	•	•
	3ottom stage/infiltrating surface area and type			•	•			•
retreatment lant	Forebay volume, surface area	•	•	•		•	•	•
	Relationship to other BMP's upstream	•	•	•	•	•	•	•
'etland lant	Wetland/swale type, surface area, and length, side slope lbottom width for swales and channels)			•	•			
	Percent of wetland surface between 0-12", 12-24", and 24-48"			•	•			
	Plant species and age of facility	•	•	•	•			

Estimation of BMP Pollutant Removal Effectiveness and Effectiveness

BMP pollutant removal effectiveness estimations are not straightforward and a wide variety of methods have been employed. Martin and Smoot (1986) discussed three types of methods to compute efficiencies, including an efficiency ratio, sum of loads, and regression of loads. Many researchers have utilized an efficiency measure based upon storm pollutant loads into and out of the BMP on a storm-by-storm basis. This weights the effectiveness considering that all storms are "equal" in computing the average removal. However, it is readily apparent that all storm volumes and their associated concentrations are not equal.

One factor that complicates the estimation of the effectiveness is that for wet ponds and wetlands, (and other BMPs where there is a permanent pool), comparing effectiveness on a storm-by-storm basis neglects the fact that the outflow for a particular event being measured may have little or no relationship to the inflow for that same event. Based upon a national characterization of rainfall (Driscoll, et. al., 1989), if a basin were sized to have a permanent pool equal to the average storm, about 60 to 70% of the storms would be less than this volume. Therefore, in many cases, flows leaving may have little or no relationship to flows entering the pond. Storm-to-storm comparisons are probably not valid. It is probably more appropriate to utilize statistical characterizations of the inflow and outflow concentrations to evaluate effectiveness or, if enough samples are collected (i.e., almost all storms monitored), to utilize total loads into and out of the BMP.

Table 4 compares three of the methods, including percent removal by storm with a statistical characterization of inflow/outflow concentration and a simple comparison of total loads in and out for the sampled storms for an example site. The removals estimated differ by up to 18 percentage points. In this record, there are several storm events where inflow concentrations were relatively low and therefore the system was not "efficient." However, it was effective at maintaining the effluent quality.

Table 4. Comparison of BMP Pollutant Removal Efficiency Techniques

Storm	Volume of Flow (ft^3) Inflow = Outflow	Concentration (mg/l) In	Concentration (mg/l) Out	Load (lbs) In	Load (lbs) Out	% Removal by storm
1	445,300	352	24	9780	670	93%
2	649,800	30	25	1220	1010	17%
3	456,100	99	83	2820	2360	16%
4	348,111	433	141	9410	3060	67%
5	730,261	115	63	5240	2870	45%
	Med	139	65			A
	Cov	1.48	.86	28,470	9,970	V 48%
	Mean	249	85			G
		Conc 66%		Loads 65%		

note: 1 lb_m = 2.2046 kg and 1 ft^3 = 0.028317 m^3

Based on these factors, it is recommended that a statistical characterization of inflows vs. outflows be utilized. Use of the log-transform of EMCs is recommended. Tests of the applicability of a log transform should be made to support the transform of data when sufficient data is available. Standard descriptive statistics, box-and-whisker plots, and normal probability plots of the transformed data for both the inflow and outflow should be employed to clearly demonstrate not only the differences in the mean EMCs, but also the effectiveness of the BMP throughout the range of influent and effluent EMCs. This approach provides the ability to determine whether any apparent differences in inflow and outflow EMC populations are statistically greater than zero. If enough data on storms is collected, (e.g., continuous samples over an extended period including base flow measurements where significant), the total loads in and out may also be an acceptable method. A graphical look at the distribution of contributing storms will often provide insight into the applicability of the method, (e.g., do a small number of large storms dominate the resulting effectiveness value).

The variability in runoff concentrations from event to event is large. In attempting to statistically characterize a BMP influent concentration (and outflow), the more data the better. As mentioned above, there are a number of types of BMP evaluations that can be conducted: (1) standard evaluation of a single BMP, testing input and output, (2) evaluation of multiple BMPs within a basin (before/after or control basin), and (3) evaluation of a BMP with multiple inlets (where it might be very difficult and expensive to evaluate the BMP utilizing input/output). All methods should require that a rigorous statistical approach be applied in selecting the number of samples to be collected to help assure detection of a given level of change.

As an example of the number of samples required to detect a "true" difference, Table 5 presents an analysis of two of the Portland monitoring stations (WCC, 1993) where 10 flow-weighted composite samples were collected. The Fanno Creek station is a large (about 1,200 acres) residential catchment that is in an open channel, while the M1 station is a smaller (about 100 acres) mixed land use station that is in a pipe. An analysis of a variance-based test was utilized with the existing data to determine how many samples are estimated to be needed to detect a 5%, 20%, and 50% change in the mean concentration at the station. The test was performed considering an 80% probability that the difference will be found to be significant, with a 5% level of significance (Sokal and Rohlf, 1969). This analysis does not consider potential seasonal effects on the collection of data as a factor. Even so, quite a large number of samples would be required to detect a 5% to 20% difference in concentrations. In many locations, given that there may be only 10 to 20 storm events per year that are large enough to monitor, it would take a number of years of sampling all storm events to be able to detect small differences.

Table 5. Analysis of Sample Sizes Needed to Statistically Detect Changes in Mean Pollutant Concentrations from 2 Stations in Portland, Oregon

		Number of Samples Required to Detect the Indicated % Reduction in Site Mean Concentration*		
Monitoring Site	Parameter	5%	20%	50%
R1 - Fanno Creek	TSS	202	14	4
Residential	Copper	442	29	6
	Phosphorus	224	16	4
M1 - NE 122nd	TSS	61	5	2
Columbia	Copper	226	15	4
Slough Mixed Use	Phosphorus	105	8	3

*80% certain of detecting the indicated % reduction in mean of the EMCs.

There are numerous examples in the literature where small differences (2 to 5%) have been reported based upon fewer samples than indicated by this analysis. This highlights the need to be more rigorous with regard to statistical testing of reported effectiveness estimates. To detect larger changes, the number of samples becomes reasonable. The mixed land use catchment in Portland is currently being studied for the effectiveness of the implementation of a number of source controls and other controls that do not lend themselves to input/output testing. Examples include maintenance changes (catch basin cleaning, street sweeping); education (business and residences); tree planting, and others. Post-BMP monitoring will be conducted along with qualitative evaluations.

Another approach that this study will be evaluating is the use of effluent data to compare to design criteria. It has been suggested by some researchers that BMPs may be able to treat only to a given concentration and therefore, if relatively clean water is entering a BMP, performance based upon efficiency may not fully characterize whether a BMP is well-designed. An example of this is based upon Rushton et al. (1997). The pond was located at the Southwest Florida Water Management District service office in Tampa. The drainage basin is 6.5 acres with about 30% of the watershed covered by roof tops and asphalt parking lots, 6% by a crushed limestone storage compound and the remaining 64% as a grassed storage area. The pond was modified twice after initial construction; therefore, there are three periods of performance data for three different designs. The first pond had an average retention time of 2 days, the second 5 days and the third 15 days. The second design added wetland features, while the third utilized deeper and larger pools.

Figure 1 shows the input and output median concentrations in log based 10 scale as well as the 95% confidence limits. The study reported that performance of the pond (defined as removal efficiency) decreased after the first modification. What appears to be evident is that the average inflow concentrations were much lower during the second period, while the outflow concentrations were about equal (less, but not statistically different from the first design). It appears that with the original and first modified designs that the effluent level was not decreased. However, one could not say that the BMP was any poorer in efficiency. The last design appears to have lowered the potential effluent concentration, but the major difference in efficiency came from the significantly higher inflow concentrations during the sampling period. This example points out the need to carefully think about whether pollutant removal efficiency is an accurate representation of how well a BMP works or does not.

In many cases, there is a need to conduct dry weather analyses between storms on BMPs with dry weather flows. It may be that pollutants captured during storms are slowly released during dry weather discharges.

Biological and downstream physical habitat assessments such as aquatic invertebrate sampling and habitat classification should be explored as an alternative to just utilizing chemical measures of effectiveness (Maxted, 1999). Long-term trends in receiving water quality, coupled with biological assessments, would likely be a much better gage of the success of the implementation of BMPs, especially on an area-wide basis.

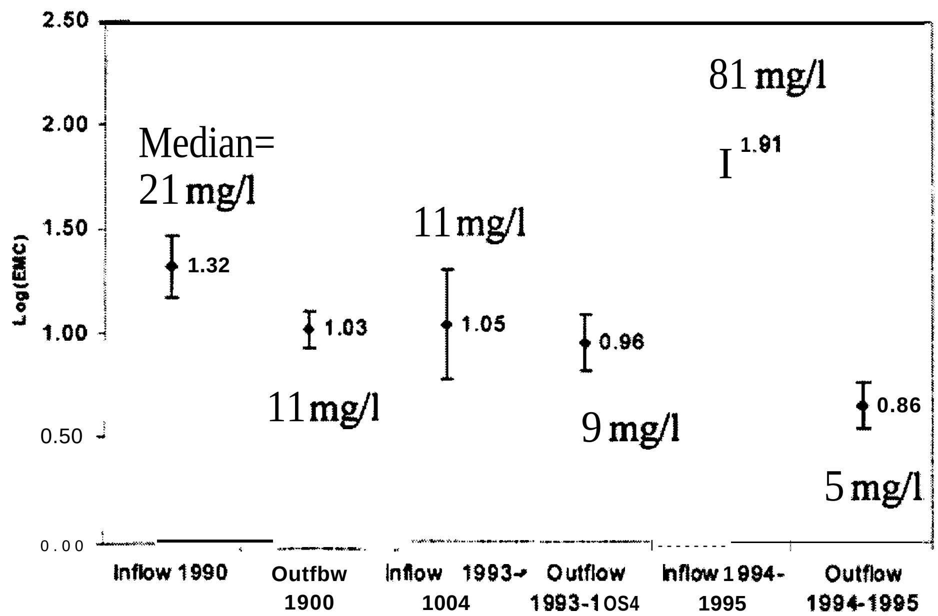

Figure 1. Inflow and Outflow Log Mean TSS Concentrations (mg/l) and 95% Confidence Limits for Different Designs of a Wet Pond Located at SWFWMD Service Office in Tampa, Florida.

Summary and Recommendations

There is a great need to have consistency with the constituents and methods utilized for assessing BMP effectiveness. This paper has presented only some of the consistency issues. It is recommended that researchers who undertake BMP effectiveness studies consider the recommendations suggested here, by Urbonas (1995) and other recommendations based upon further analysis of this subject. It is the authors' opinion that EPA should require studies receiving federal funding to conduct BMP effectiveness studies that utilize standard methods as suggested here, together with much still-needed detailed guidance on data collection and sampling methods to improve data transferability.

Acknowledgments

The authors wish to thank Gene Driscoll, Jonathan Jones, Bob Pitt, Bill Snodgrass, and Larry Roesner for their helpful discussions and comments on the subject. Jonathon Jones, Jane Clary, and John O'Brien from Wright Water Engineers developed the Database Structure and Platform as members of the ASCE project team. The Urban Water Resources Research Council has provided very beneficial support and feedback. Finally, the assistance by EPA in funding this cooperative agreement is acknowledged as well as the helpful participation of Eric Strassler and Jesse Pritts in reviewing our work.

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Texas Nonpoint SourceBOOK Is Now On-Line!
http://www.txnpsbook.org

John Promise, P.E.
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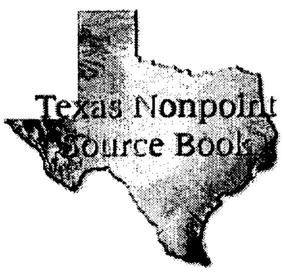
North Central Texas Council of Governments, and
Chair, Water Resources Management Committee, American Public Works Association

Keith Kennedy
North Central Texas Council of Governments

Robert W. Brashear, Ph.D.,
Camp Dresser & McKee Inc.

Summary



The Texas *Nonpoint SourceBOOK* is an Internet-based resource that has been developed to assist public works officials across Texas with storm water management. The *SourceBOOK* provides basic information about storm water quantity and quality impacts, outlines how to develop and implement a local storm water management program, identifies localized water quality issues, and provides an interactive database of more than 100 Best Management Practices (BMP's) to use in a variety of situations.

The Texas *Nonpoint SourceBOOK* provides information for the novice as well as the experienced storm water manager. The project was funded by the Environmental Protection Agency and matching funds from 20 local governments across Texas. The North Central Texas Council of Governments (NCTCOG) served as project administrator. The *SourceBOOK* was developed by a consulting team lead by Camp Dresser & McKee Inc. (CDM). A Project Management Committee of local governments provided project oversight. After extensive review via the Internet, the *SourceBOOK* was officially endorsed by the Executive Committee of the Texas Chapter – American Public Works Association (APWA). Five training workshops were conducted across the state. The *SourceBOOK* is intended to be a living resource, with additions and changes occurring continually in response to input from users. A feedback page allows direct input from the Internet.

Why a *Texas Nonpoint SourceBOOK*?

Recognizing the need for improved communication, cooperation, and education statewide on stormwater issues, a *Statewide* Storm Water *Quality* Task Force was established by the Executive Committee of the Texas Chapter - American Public Works Association. At an organizational meeting in February 1994, a Steering Committee and subcommittees were formed. The various subcommittees immediately tackled the task of identifying current issues and needs regarding storm water quality and nonpoint source pollution, particularly with respect to the needs of public works officials across Texas.

Already known was that nonpoint sources, including stormwater, contribute to water pollution problems. The Water Quality Subcommittee began to review data from the Texas Clean Rivers Program, available nonpoint source monitoring data, and the State's Nonpoint Source Water Pollution Assessment Report. They presented this assessment at subsequent meetings of the Task Force. Water quality problems were known, but not how best to address them.

What was not known was the applicability and cost-effectiveness of Best Management Practices (BMPs) for addressing many of the typical water quality pollutants: bacteria, pesticides, nutrients, metals, toxic chemicals, and others. The Best Management Practices (BMP) Subcommittee surveyed local governments across Texas on BMP implementation but found little technical data. It was evident that until questions such as applicability and cost-effectiveness could be answered, local governments would not invest limited public funds on storm water controls.

A project was formulated that would provide the assistance local governments needed by developing an internet-based resource of storm water management information. At the time it was a striking idea, since the Internet was very new and few local governments had any "on-line" experience. Using the emerging Internet would provide ready electronic access and would allow for the use of new technologies in communication. This resource was to be called the Texas *Nonpoint SourceBOOK,* and would be developed in both "hardcover" and electronic form. A grant application, submitted to the Texas Natural Resource Conservation Commission under the Section 319(h) Nonpoint Source Program, was awarded in the spring of 1996. Work on the project began in September, 1996.

How Was the *Texas Nonpoint SourceBOOK* Developed?

The North Central Texas Council of Governments provided staff support and general administrative oversight. To guide the development of the *SourceBOOK,* a Project Management Committee was established from the Texas Chapter-APWA membership. Among its first tasks was issuing a Request for Proposals for professional consultant assistance, and selecting the consultant finalists. From the finalists the Committee selected a consultant team led by the firm Camp Dresser & McKee Inc., in association with Espey Huston & Associates, Inc.; Center for Watershed Protection; Booth, Ahrens & Werkenthin, P.C.; Carter Burgess; and Pavlik & Associates. Together, the committee and consultants used the State's Nonpoint Source Water Assessment Report and supporting information to identify particular pollutants from priority watersheds and related pollution prevention BMPs.

During FY97, the Project Management Committee worked with the consultant to establish the format of the *Texas Nonpoint SourceBOOK* on the Internet. Presentations on local BMP experiences were made at the TX-APWA Short Course at Texas A&M in February, 1997. Initial consultant materials were reviewed by the TX-APWA general membership at its summer, 1997, Annual Meeting. A draft of the *Texas Nonpoint SourceBOOK* was presented to the TX-APWA general membership at the February 1998 Short Course, and local government comments were solicited.

The TX-APWA Executive Committee endorsed the *Texas Nonpoint SourceBOOK* in February, 1999. It is available through the Internet and on CD-ROM for use by local governments across Texas. The Committee and consultant conducted technology transfer and training workshops on storm water management and the *Texas Nonpoint SourceBOOK* at five regional one-day workshops across Texas during February and March of 1999.

How is the *Texas Nonpoint SourceBOOK* Organized?

The *SourceBOOK* is designed to make use of the capabilities of the Internet. This includes the ability to organize and present textual and graphical information through common browser formats, as well as providing active links to related sites. The design of the content of the *SourceBOOK* maximized the use of existing web sources wherever possible.

The content of the *SourceBOOK* consists of a set of modules:

Introduction and Overview

- About This Site
- Frequently Asked Questions (FAQs)
- Related Links
- Nonpoint Source News

- Post Your Feedback

Module 1 -- Nonpoint Source Management 101

- History of Nonpoint Source Management
- Urban Nonpoint Source Primer
- Controlling Urban Runoff--Guidance for Beginners
- Selecting the Right BMP -- Guidance for Beginners
- Planning Your Stormwater Management Program - Guidance for Beginners
- Glossary

Module 2 -- Urban Runoff Management Programs

- Introduction
- The Planning and Goal Setting Process
- Planning and Program Approaches
- Funding Mechanisms
- Measuring Effectiveness of Management Programs
- Implementation Strategies
- Case Studies
- Bibliography
- Additional Resources

Module 3 -- Characterizing Urban Waterways

- Urban Runoff Flow and Water Quality
- Assessing Urban Waterways
- Water Quality and Other Watershed Physical Characteristics in Texas

Module 4 -- Runoff Quality Best Management Practices

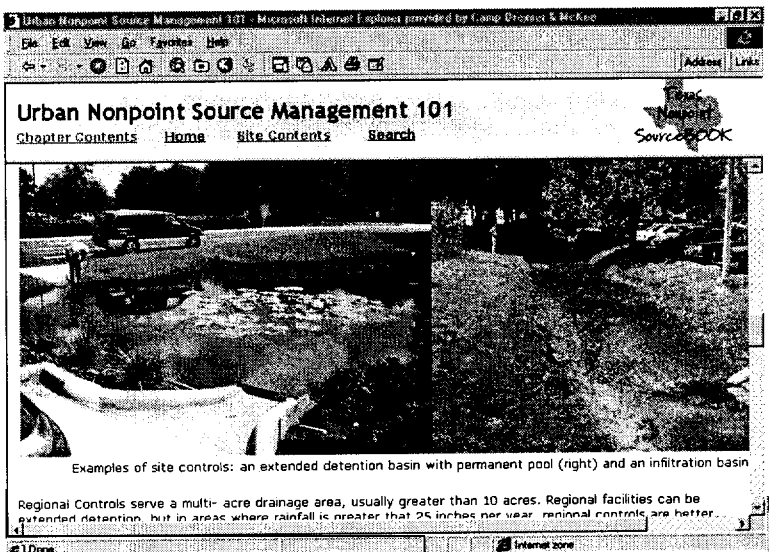
- Selecting Management Practices
- Housekeeping Practices
- Source Control Practices
- Treatment Control Practices
- Interactive BMP Selector

What Does Each Module Provide in the *Texas* ***Nonpoint SourceBOOK***?

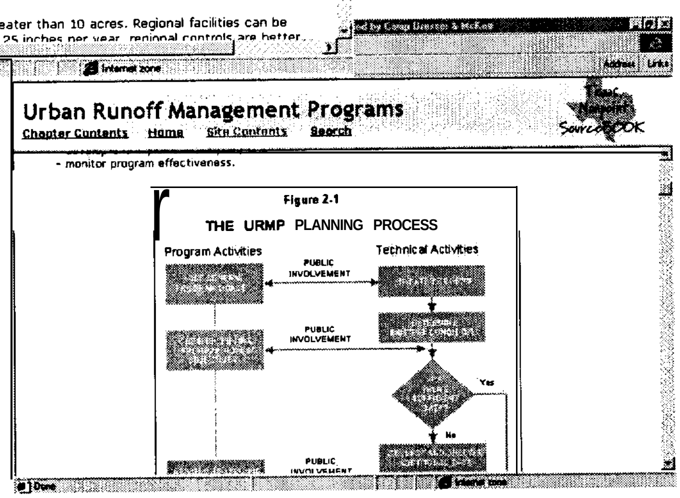
Module 1, "Nonpoint Source Management 101," is a primer for beginners on urban stormwater management. It quickly establishes that storm water quality <u>and</u> quantity management need to be addressed as one integrated program within a local government. It provides guidance on regulatory issues, basic axioms of runoff control, and the use of pollution prevention, source and treatment controls.

Module 2, "Urban Runoff Management Programs," describes the process to be used to manage urban runoff within the overall framework of the city, county, or special district. Particular attention is placed on the key institutional and financial components necessary for a successful ongoing program.

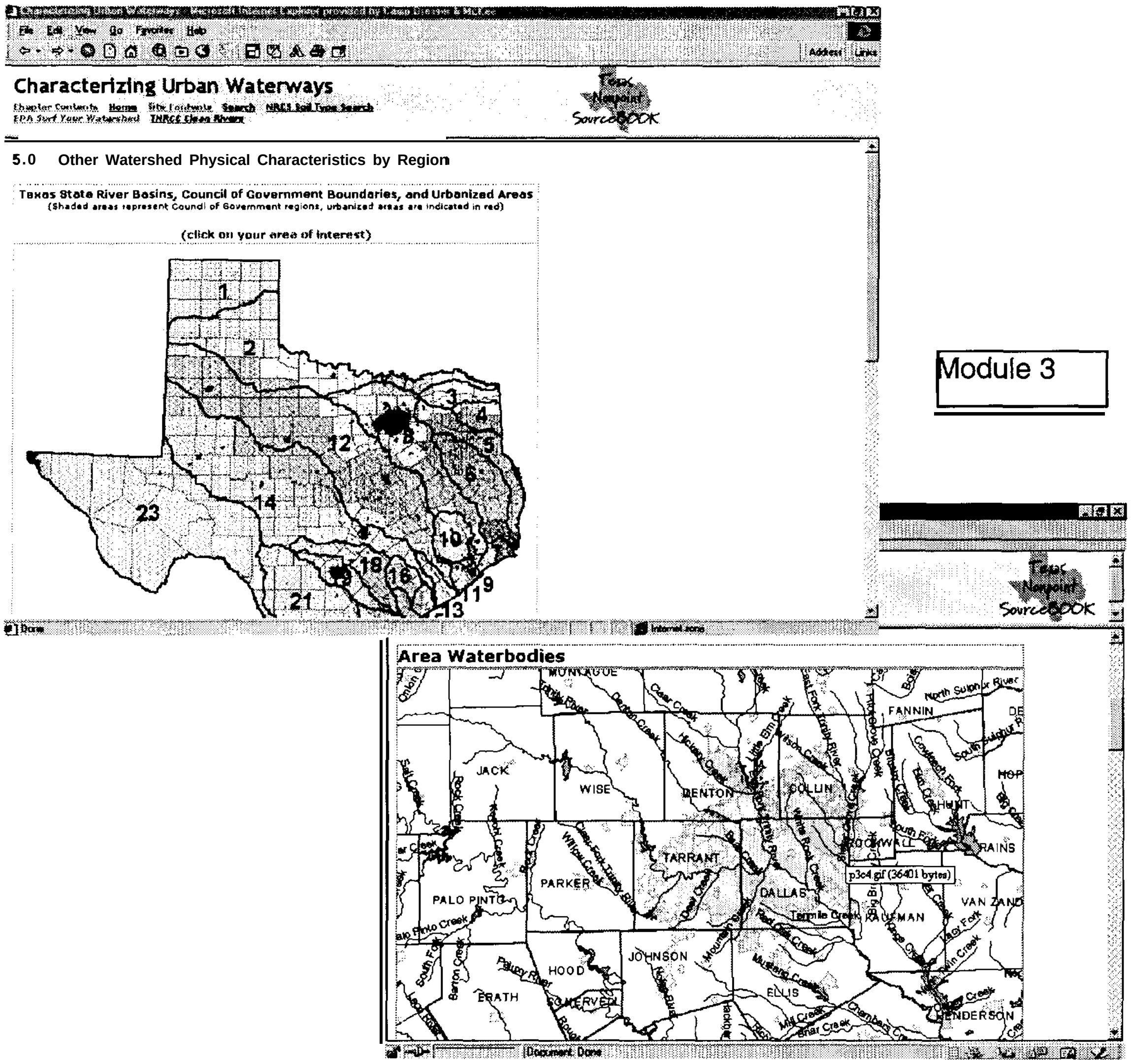
Module 3, "Characterizing Urban Waterways," begins with a generic discussion of urban runoff flow and water quality relationships. Considerable attention is then given to proper techniques for monitoring urban waterways and stormwater runoff. The majority of the module focuses on Texas-specific information. Descriptions of known water quality problems can be accessed for the entire state. Each regional planning area and basin has specific information on water bodies,



Module 1



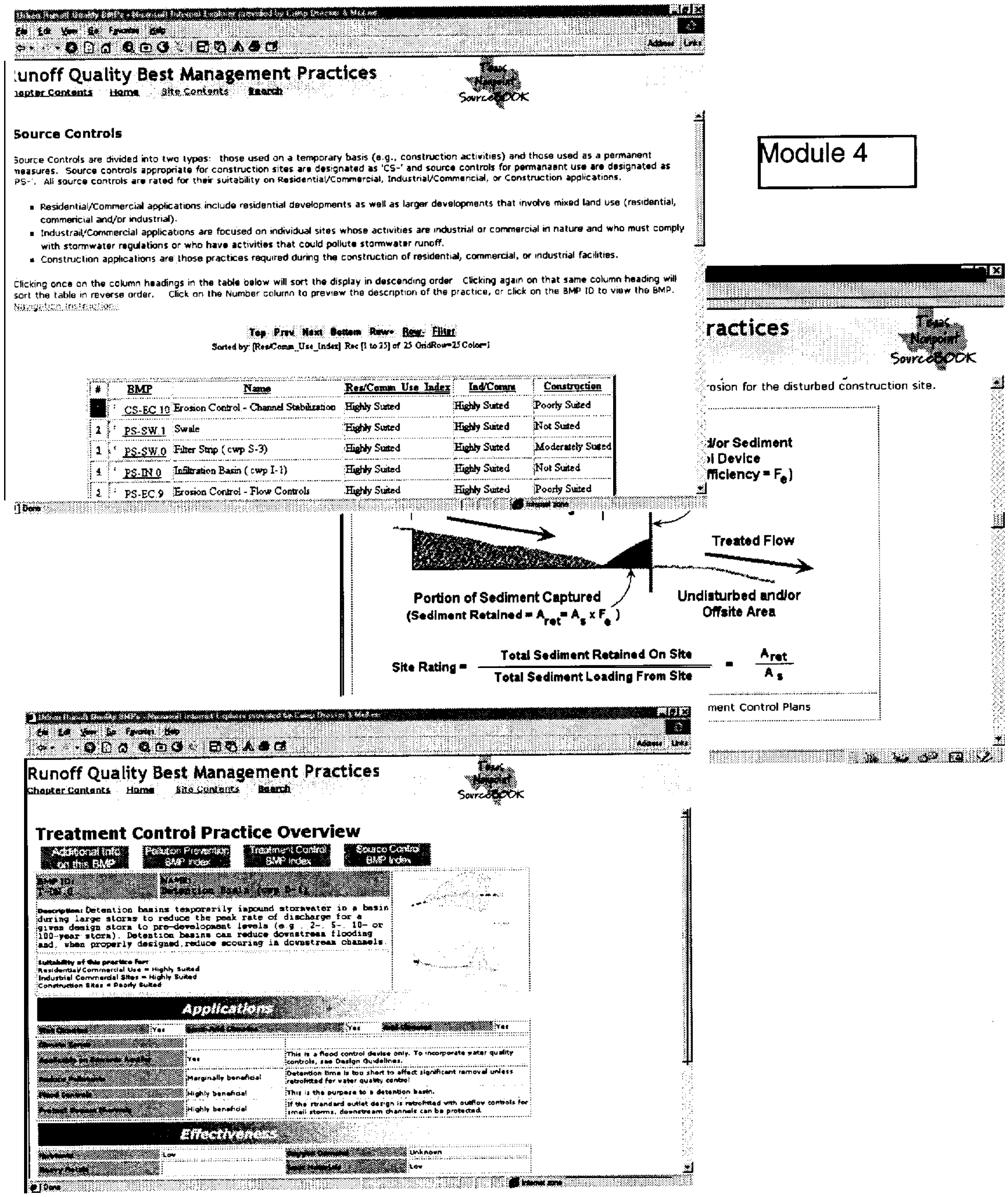
Module 2



watershed characteristics, annual precipitation and runoff, major soil types, and the like. There are many "hot" links to real-time gauging stations, local programs, and state/federal sites, such as EPA's Surf Your *Watershed.*

Module 4, "Runoff Quality Best Management Practices," provides guidance on the selection of Best Management Practices for pollution prevention, source control, and treatment control. Considerable effort was placed on gathering the most current information on more than 100 BMPs and review by the Project Management Committee of local governments. Each BMP includes detailed information, such as performance data, photographs, and relevant reference citations. An innovative BMP Interactive Selector was developed for the *SourceBOOK.* It enables the user to peruse BMP's in each category, or to input several characteristics specific to their situation and request a set of the most applicable BMPs.

Module 4



Runoff Quality Best Management Practices
Chapter Contents Home Site Contents Search
Source Controls
Source Controls are divided into two types: those used on a temporary basis (e.g., construction activities) and those used as a permanent measures. Source controls appropriate for construction sites are designated as 'CS-' and source controls for permanent use are designated as 'PS-'. All source controls are rated for their suitability on Residential/Commercial, Industrial/Commercial, or Construction applications.
Residential/Commercial applications include residential developments as well as larger developments that involve mixed land use (residential, commercial and/or industrial).
Industrial/Commercial applications are focused on individual sites whose activities are industrial or commercial in nature and who must comply with stormwater regulations or who have activities that could pollute stormwater runoff.
Construction applications are those practices required during the construction of residential, commercial, or industrial facilities.
Clicking once on the column headings in the table below will sort the display in descending order. Clicking again on that same column heading will sort the table in reverse order. Click on the Number column to preview the description of the practice, or click on the BMP ID to view the BMP.
Top Prev Next Bottom Row Filter
BMP
Name
Res/Comm Use Index
Ind/Comm
Construction
CS-EC 10 Erosion Control - Channel Stabilization Highly Suited Highly Suited Poorly Suited
PS-SW 1 Swale Highly Suited Highly Suited Not Suited
PS-SW 0 Filter Strip (cwp S-3) Highly Suited Highly Suited Moderately Suited
PS-IN 0 Infiltration Basin (cwp I-1) Highly Suited Highly Suited Not Suited
PS-EC 9 Erosion Control - Flow Controls Highly Suited Highly Suited Poorly Suited
ractices
rosion for the disturbed construction site.
d/or Sediment
l Device
fficiency = F_e)
Treated Flow
Portion of Sediment Captured
(Sediment Retained = A_{ret} = A_s x F_e)
Undisturbed and/or Offsite Area
Site Rating = Total Sediment Retained On Site / Total Sediment Loading From Site = A_{ret} / A_s
ment Control Plans
Runoff Quality Best Management Practices
Chapter Contents Home Site Contents Search
Treatment Control Practice Overview
Additional Info on this BMP
Pollution Prevention BMP index
Treatment Control BMP index
Source Control BMP index
Description: Detention basins temporarily impound stormwater in a basin during large storms to reduce the peak rate of discharge for a given design storm to pre-development levels (e.g. 2-, 5-, 10- or 100-year storm). Detention basins can reduce downstream flooding and, when properly designed, reduce scouring in downstream channels.
Applications
Effectiveness

A Comparison of the Long-Term Hydrological Impacts of Urban Renewal versus Urban Sprawl

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Abstract

Recent concern over environmental and economic impacts of urban sprawl has focused renewed attention on the importance of making full use of existing urban areas. Revitalizing former industrial, commercial, and residential areas often involves changes in land use type or intensity of use. It is important to have the ability to evaluate the long-term hydrological impacts of such changes. These impacts can then be placed within the context of impacts that similar land uses would have if a decision were made to place them in the urban fringe (urban sprawl) rather than in existing urban areas (urban renewal).

In this study, we illustrate how the Long-Term Hydrological Impact Analysis (L-THIA) tool can be used to compare the hydrological impacts of land use change in existing urban areas versus change in the urban fringe. L-THIA is a simple, comparative tool that requires the user to provide information on land use and soil type for existing and future/planned conditions. The tool combines this information with local rainfall data to calculate long-term average annual surface runoff under existing and future/planned conditions. L-THIA analyses can be run directly at our web site for locations throughout the U.S. where the curve number technique is already routinely used (http://danpatch.ecn.purdue.edu/~sprawl/L-THIA). By performing analyses of renewal versus conversion of agricultural land at the urban fringe, it is possible to provide a comparative assessment of impacts. This initial comparison can be helpful in educating the general publicand decision-makers, thereby raising awareness of this element of the set of variables that are considered in land use decisions.

Introduction

Because almost every major North American city had been founded by 1900, the dominant form of urban development during the 20th Century has been growth on the outer edges of existing cities, or just beyond city limits (Orum, 1995). With improvements in transportation and communications, the need for people to be clustered in high-density central areas has decreased (Chinitz, 1991), encouraging decentralization, suburbanization, and sprawl. In the United States, 87% of the population now lives in metropolitan areas and their hinterlands (Angotti, 1995), and steady infilling between urban areas has resulted in the development of megalopolises such as the Philadelphia - Boston - Washington DC - New York urban corridor. Even metropolitan areas which are stagnating or declining in terms of total population are still growing in terms of total built area because of low-density suburban growth (Johnston, 1982).

Decentralization and suburbanization have changed the relative importance of the core areas of cities (Richardson, 1982). Although these central areas were the sites of initial city growth and development, many cities are now faced with the challenge of revitalizing these once vibrant central industrial, commercial, and residential areas that have been in decline in recent decades:. The following quote reflects efforts to slow the tide of migration from urban centers.

"To combat the number of people fleeing [Chicago] for the suburbs, developers have lured middle-class home buyers back with promises of safe neighborhoods and affordable homes. Chicago also leads the nation in converting office and warehouse property into residential space such as condominiums and rental units, often targeted to low- and moderate-income buyers." (Heavens, 1999)

At the same time that city administrations have been coping with the challenges of urban core renewal, suburban and rural communities have become increasingly concerned about the environmental, economic, social, and aesthetic impacts of continued urban growth at the fringes of developed areas (these later concerns are often grouped under the term urban sprawl). Preservation of prime farmland and protection of rural areas have become important concerns, alongside a growing emphasis on combating the impacts of continued sprawl on flooding, groundwater recharge, air pollution, climate, ecology, and habitat fragmentation (Schueler, 1994). Although there is considerable interest3 in revitalizing urban cores, especially if this reduces urban sprawl, to accomplish this requires that the decision-making process for urban and suburban planning include consideration of the environmental as well as the economic aspects of land use.

Land use decisions are highly complex, involving consideration of economics, infrastructure, politics, labor and population dynamics, and the environment. The planning process requires collection and comparison of a wide array of data, usually with the goal of providing a planned solution that meets goals based on sustainable growth in industry and commerce. However, increasing public and political concern over the environmental aspects of urban development has raised the profile of efforts to develop efficient and environmentally sustainable urban environments. The key components of environmentally sound urban development include land use patterns that minimize environmental impacts (Arendt, 1996), efficient automobile and pedestrian traffic, and the use of energy saving and environmentally sound building designs. When attempting to balance economic and environmental concerns, it is important to quantify the differential environmental impacts of alternate land-use scenarios. Objective measures of differential impacts provide a rational basis for decision-making. In addition, they can be used to educate the public and key decision-makers in government and the private sector about the level of environmental benefit that can be gained from alternative land-use decisions.

The aim of the work presented here is to demonstrate the application of an impact assessment tool in evaluating the long-term hydrologic impact of development consistent with urban renewal versus the impact of an identical development located at the urban fringe. Although the general outcome of such a comparison is unlikely to surprise anyone, the advantage of quantifying differential impacts is in providing an objective numeric measure that is much easier to include in decision-making than vague subjective assessments of environmental benefits.

Long-Term Hydrologic Impact Assessment (L-THIA)

In response to concerns from local planners that they had no simple, objective way to assess the impacts of alternate development plans on surface water runoff and groundwater recharge, a Long-Term Hydrologic Impact Assessment tool (L-THIA) has been developed (Harbor, 1994; McClintock et al., 1995; Ogden, 1996; Grove, 1997; Bhaduri et al., 1997; Bhaduri, 1998; Minner, 1998; Minner et al. 1998; Lim et al., 1999; Leitch and Harbor, in press). L-THIA uses readily available data on soils, climate, and land use to estimate long-term surface water runoff. By running the model for current conditions, and then with changed land uses, the user can simulate the potentialimpact of land use change. The method, initially developed as a simple spreadsheet application (Harbor, 1994), is based on the U.S. Department of Agriculture's curve number (CN) method for relating precipitation and runoff as a function of land use and soil type (USDA, 1983, 1986). The CN method was selected because it forms the basis of other commonly used hydrologic models, thus the data required for its use is readily available in most planning settings. Because of the reliance on the CN method, L-THIA applies directly to those areas where the CN method is routinely used. Subsequent development of the L-THIA method has included provision of a Geographic Information System (GIS) version (Grove, 1997), addition of nonpoint source pollution loadings to land uses (Bhaduri, 1998), and development of an Internet--accessible version of the method (Lim et al., 1999).

In the curve number technique, the land use and hydrologic soil type of an area are used to derive a CN value (values typically range from 30 to 98). For any given daily precipitation, surface runoff is then computed from empirically based relationships between rainfall, CN, and runoff. Although most commonly used to estimate runoff for extreme storm events, in L-THIA the CN technique is used to determine daily runoff for a 30-year time series of daily precipitation values.

Average annual runoff is calculated for each CN to provide a measure of long-term average impact, rather than simply impact on isolated extreme storm events. To compare different land use change options, pre-development and post-development average annual runoff can be calculated for each scenario. The L-THIA method is freely available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA. This site includes information on the technique and its application, as well as access to US climate and soils data necessary to run analyses. Users can submit land use and soil information through a spreadsheet-style interface (Figure 1). Analyses are performed on a server at Purdue University and results are delivered back to the user in the form of tables and graphs.

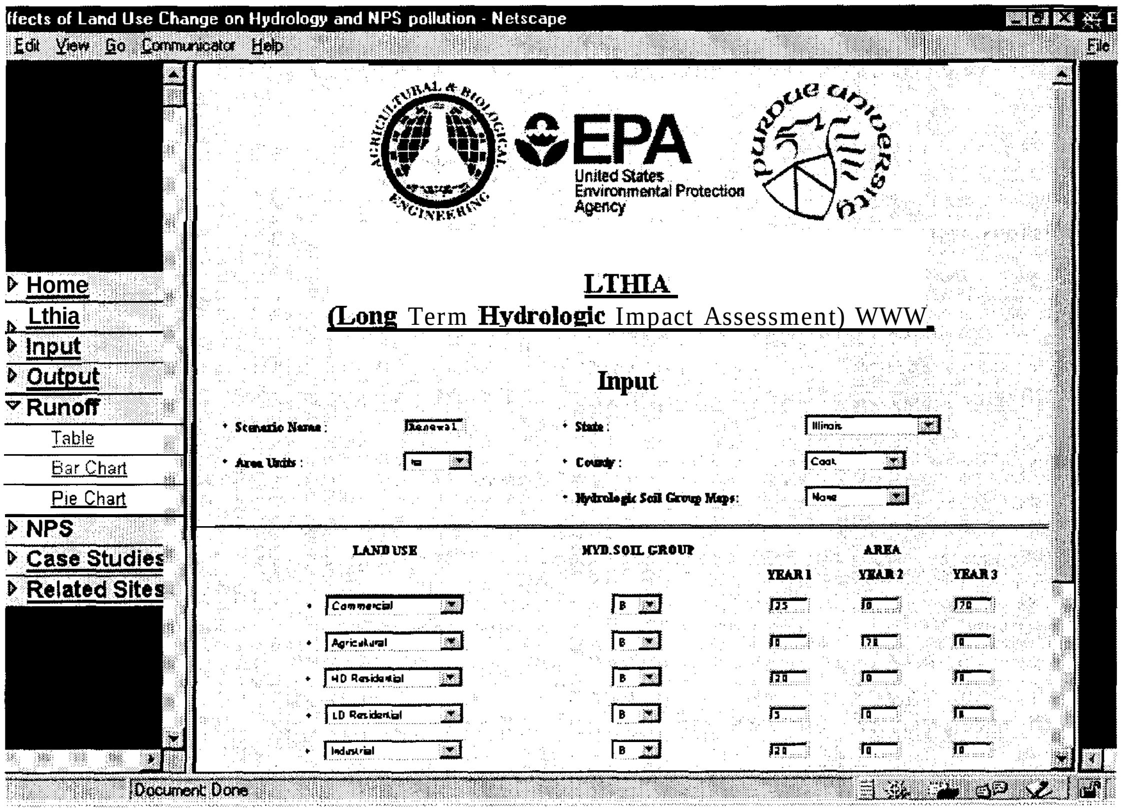

Figure 1. L-THIA WWW Input Screen at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA.

A Comparison of Core Renewal versus Fringe Development

Study Scenario

The L-THIA tool can be used to examine the relative impact of land use change in the form of an urban renewal project; replacing underused or abandoned commercial, residential, and industrial buildings in an urban core region; versus an urban sprawl project; replacing agricultural land at the edge of a city. For the sake of illustration, consider planning a 70 Ha major commercial development with urban core and urban fringe location alternatives. Although the location decision-making process will be driven by economic and infrastructure concerns, also assume that differential environmental impact is important in decision--making, perhaps as a result of political or regulatory pressure. In the context of improving urban environments then, an important question is the extent to which placing this development in an urban core region would have different hydrologic impacts than placing it at the city fringe.

To simulate this situation, consider two possible sites in the Chicago area. The first is in the urban core, and currently consists of a mix of residential, industrial, and commercial properties that are unused or underused (Figure 1). The second possible site is on the urban fringe, and currently is used for agriculture. For simplicity we assume that both sites are on the same type of soil (from a hydrologic perspective), although in a real world example this might not be the case. In each case, we use the L-THIA web tool to analyze how average annual runoff will change if the site is converted to solely commercial use (Figure 1). In the L-THIA input and output, the urban core site is labeled "YEAR 1 ", the urban fringe agricultural site is labeled "YEAR 2" and the commercial land use for both sites is labeled "YEAR 3." The L-THIA web tool uses the "YEAR" designation for different scenarios because analyses are typically for land use changes over time.

Results

For the example described here, placing a commercial development in an urban core region, replacing an existing mix of urban land uses, increases average annual runoff by 58% compared to the initial situation (Table 1 and; Figure 2). Note that the levels of impact given in Table 1 do not depend on the size of the commercial development; the same percent increase applies regardless of area. Runoff increases because land uses with less impervious cover, such as residential, are replaced by commercial land use that has a higher percentage of impervious area. In contrast, for the urban fringe location, replacing agriculture with commercial use increases runoff by 670% (Table 1 and Figure 2), a ten-times greater impact. Runoff increases so dramatically because agricultural use on relatively permeable soil is replaced by very extensive impervious surfaces.

Table 1. Average annual runoff deoths and chanae for commercial development (post-development) in the urban core versus the urban fringe. Results are for the specific example described in the text."

	Pre Development Average Annual Runoff (mm)	Post Development Average Annual Runoff (mm)	Increase in Runoff (%)
Urban Core	81.8	129.3	58
Urban Fringe	16.8	129.3	670

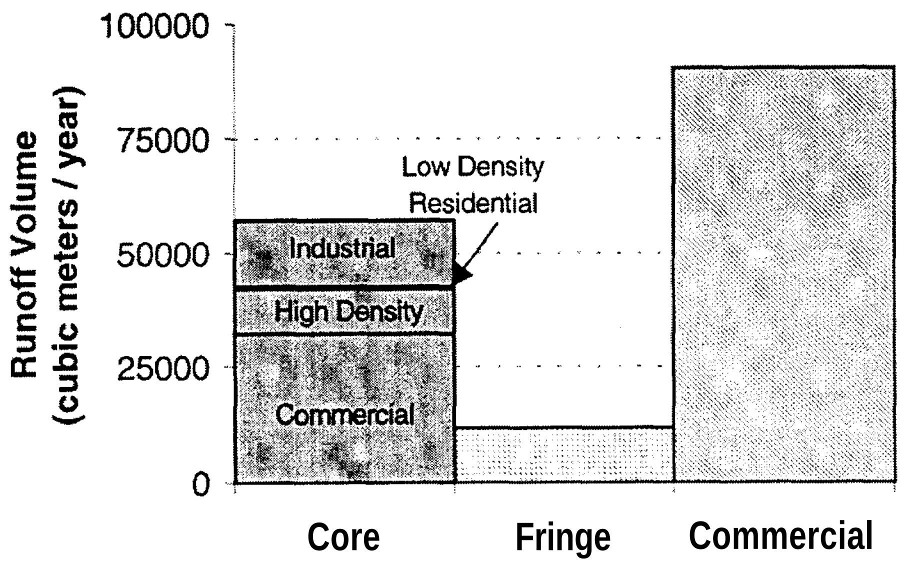

Figure 2. Average annual runoff volumes for commercial development, the urban core mixed-use, and the urban fringe agricultural use. The much larger difference between the fringe location runoff volume and the commercial case indicates that fringe development will have the largest hydologic impact. Note that the runoff volume is simple the average annual runoff depth (Table 1) multiplied by the site area. Results are for the specific example described in the text.

Discussion and Conclusions

The straightforward example presented here indicates that developing a commercial site in an urban core versus and urban fringe location can have a very significant impact on the level of disturbance of the hydrologic regime. For the Chicago example presented here, the urban fringe location produces an approximately ten times larger impact than the urban core location. Clearly, from a solely hydrological standpoint, the urban core location is a better choice than the fringe location. Although this is a hypothetical example, it illustrates the relative ease of use of the L-THIA tool, and more importantly demonstrates an accessible way to provide a quantitative estimate of the relative impacts of different land use decisions. More complex land use mixes and soil types can be run on the L-THIA web tool, either in the spreadsheet version or in a GIS version also available at the web site. Thus, more sophisticated comparative analyses can be performed.

In most cases, an L-THIA analysis provides a result that shows that renewal of existing areas has less hydrologic impact than development of an area with rural use. This is not a surprise, rather the value of the tool is that it provides a context for understanding and considering the magnitude of this difference in the decision-making process. For areas where problems such as groundwater supply and downstream flooding are important, the scale and magnitude of the hydrologic impact can be of considerable importance and can be considered alongside other concerns, such as infrastructure and economic viability. We suggest use of tools such as L-THIA as part of the planning process, to ensure that land use decisions are made after consideration of a full range of concerns, including environmental parameters as well as economic, infrastructure, and political issues.

Acknowledgements

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Comparative Nutrient Export And Economic Benefits of Conventional And Better Site Design Techniques

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Better site design describes a fundamentally different approach to the design of residential and commercial development projects. It seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase the amount of natural land set aside for conservation, and to use pervious areas for more effective stormwater treatment.

When designing new residential developments, planners have the opportunity to reduce stormwater runoff and pollutant export through better site design techniques. The better site design techniques applied to these developments are referred to here as "open space design," and present an alternative to conventional residential subdivisions. Also known as cluster development, open space design concentrates density on one portion of a site in order to conserve open space elsewhere by relaxing lot sizes, setbacks, frontages and road section and other lot geometry. Open space design also consists of:

- installing narrower streets and shorter driveways
- spreading stormwater runoff over pervious areas
- using open channels rather than curb and gutter
- clustering development to conserve forests and natural areas
- reducing the area devoted to turf
- protecting stream buffers
- enhancing the quality of septic system effluent in areas where sewage is disposed of on-site

When these techniques are applied together, the cumulative benefits of better site design can be impressive. Documenting the precise benefits is difficult, however, since few developments incorporating better site design techniques have been built, let alone monitored.

As most better site design techniques are non-structural in nature, the achievable benefits will vary depending on the unique characteristics of each development site and the actual site planning practices applied. Also, since better site design techniques are commonly applied together, it has been difficult to accurately quantify their individual nutrient removal benefits. Many local governments, consultants, and developers have expressed a strong desire for clear documentation of these presumed benefits.

To help meet this need, the Center for Watershed Protection (CWP) recently completed a study to document the comparative nutrient export and economic benefits of conventional and better site design techniques. The simple assessment methodology analyzed both the residential and commercial environment through four real-world development case studies in the Chesapeake Bay watershed. This paper presents the results of the residential component of that project, including the incorporation of open space design techniques into the redesign of two residential case studies; the resultant hydrologic, nutrient export, and economic benefits; and finally, the implications of our findings for the watershed manager.

Methodology

The basic method used in the Nutrient Loading from *Conventional and Innovative Site* Developmentproject (Caraco, et al., 1998) conducted by CWP is a redesign analysis that compares conventional and better site design at actual project sites using a simplified model.

CWP first assembled plans of previously developed sites representative of typical development scenarios across the Chesapeake Bay, including a medium-density residential development from Virginia's Piedmont, a large-lot single family residential subdivision from Maryland's Eastern Shore, a retail strip mall from Frederick County, Maryland, and a commercial office park located outside of the District of Columbia in suburban Maryland. Each site was then "redesigned" using better site design techniques.

The Simplified Urban Nutrient Output Model (SUNOM) was then used to compare each conventionally designed site to the redesign. SUNOM is a spreadsheet model that computes the hydrologic budget, infrastructure cost and nutrient export from any site, using common site planning variables. The model provides watershed practitioners with a simple tool to compare the costs and benefits of better site design. It is not meant to be used as a method for determining actual stormwater runoff and nutrient loading from a development site. To obtain accurate numbers for this, a more detailed model should be used or on-site monitoring should be conducted.

Model input includes basic site planning variables that can be directly obtained or measured from a typical development submittal to a land use authority, including total drainage area, length of sidewalks, total impervious cover, linear feet of roads, lawn cover, utilities (length and type), forest cover, size, type, and length of stormwater conveyance, riparian forest cover, size and type of stormwater practices, soil type(s), and method of wastewater treatment. Default data are provided for many parameters and many of these assumptions can be changed based on site specific information.

SUNOM is governed by the principles of a simplified water balance. In addition to annual runoff and infiltration, SUNOM computes the annual nutrient load from each development site in pounds. In brief, the surface nutrient export from each site is estimated using the Simple Method (Schueler, 1987). This export is then adjusted to reflect the mean removal capability of stormwater BMPs where present (Schueler, 1997). The subsurface component of the model utilizes annual subsurface recharge rates (based on the site's prevailing hydrologicsoil group) and monitored baseflow nutrient concentrations in the receiving water to estimate the annual subsurface nutrient export from urban areas. These values are then adjusted for the area of the site that cannot recharge (i.e., impervious cover) or are hindered from infiltrating by other conditions (e.g., compacted urban turf). The model also calculates the cost of development utilizing previously published or user-specified unit costs and predictive equations for infrastructure, stormwater management, landscaping, and septic systems.

For each case study, SUNOM was used to compare the annual hydrologic budget and annual nutrient export under five development scenarios: pre-developed conditions, conventional design without stormwater practices (uncontrolled), conventional design with stormwater practices (controlled), design incorporating better site design techniques without stormwater practices (uncontrolled), and design incorporating better site design techniques with stormwater practices (controlled). The cost of development associated with each design was also estimated.

Case Study #1: Duck Crossing, A Low Density Residential Subdivision

Duck Crossing, a large-lot residential development, is located in Wicomico County on Maryland's Eastern Shore. Prior to development, the parcel was representative of the typical terrain on Maryland's coastal plain, with very little gradient. The site contained tidal and non-tidal wetlands, natural forest, meadow, the 1 00-year floodplain, as well as three existing dwellings with on-site sewage disposal.

The large-lot subdivision of single family homes, constructed in the 1990's, (Figure 1) contains eight new residential lots, each of which are 3 to 5 acres in size with houses set far back from the street. The street is wide given the few homes that are served, ends in a large cul-de-sac, and is lined with a sidewalk. Each lot has an on-site private septic

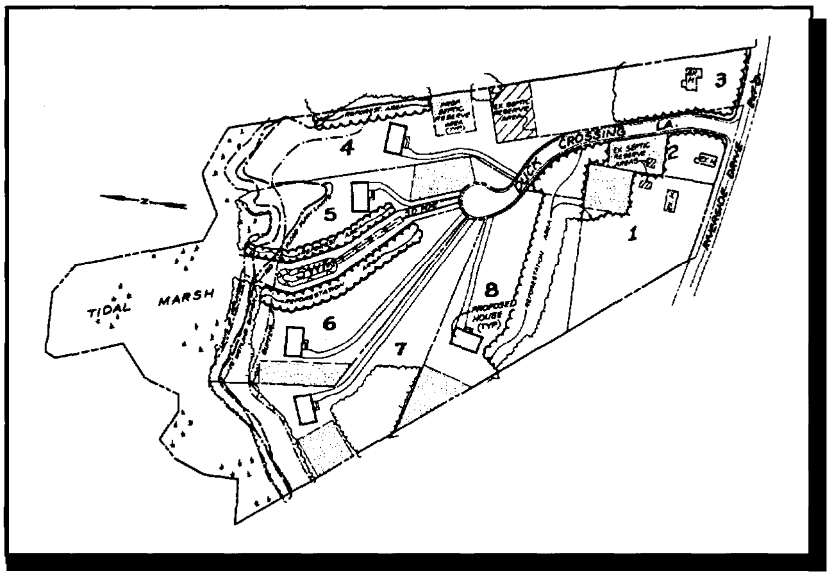

Figure 1. The conventional design of Duck Crossing, a low density residential subdivision on Maryland's Eastern Shore.

system, with a septic reserve field of about 10,000 square feet. Individual home property lines extend to the protected tidal marsh, which is the only common open space on the site. Stormwater management consists of street runoff conveyed by curb and gutter to a storm drain system that discharges to a small wet pond.

The major better site design techniques applied when redesigning this site (Figure 2) included:

- conservation of tidal and non-tidal wetlands and forested areas
- a 100-foot buffer along tidal and non-tidal wetlands
- clustering development to provide additional open space
- identification of potential development and open space areas based on location of sensitive areas, 100-year floodplain, and potential septic field areas
- distribution of stormwater treatment practices throughout the site
- use of a narrower access road; shorter, shared driveways; and wood chip paths through community open space instead of sidewalks along the road
- use of shared septic systems utilizing more advanced re-circulating sand filter technology

The open space design resulted in reduced impervious cover, reduced stormwater runoff, increased stormwater infiltration, and reduced infrastructure cost over the conventional design.

Case Study #2: Stonehill Estates, A Medium-Density Residential Subdivision

Stonehill Estates is located in Stafford County just north of Fredericksburg, Virginia. The original site was almost entirely forested in a mix of mature deciduous hardwoods, with perennial and intermittent streams, and non-tidal wetlands. An existing network of public water and sewer lines serves the site and road access to the subdivision is by two existing streets.

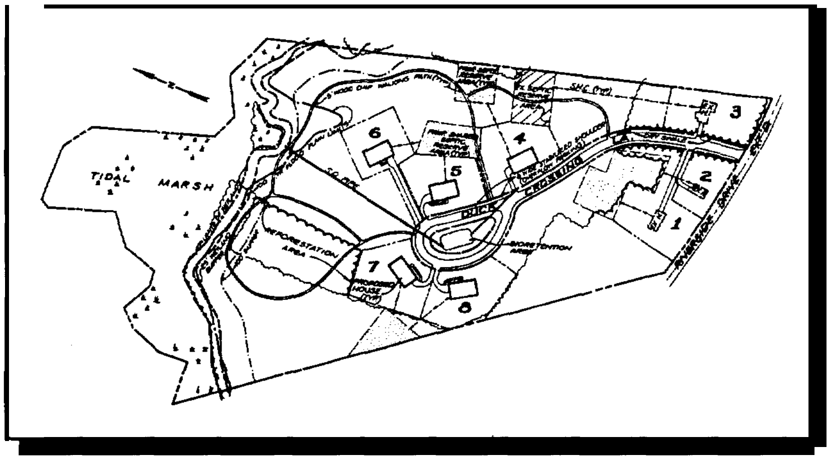

Figure 2. The open space design of Duck Crossing.

The conventional design produced a total of 108 house lots, each of which are about 9000 square feet in size (Figure 3). The subdivision is quite typical of a medium-density residential subdivision developed in the last two decades in the Mid

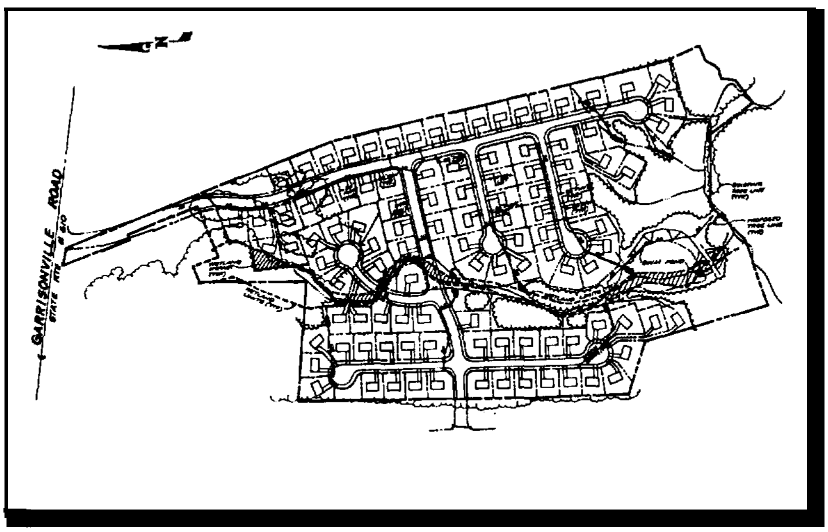

Figure 3. The conventional design of Stonehill Estates, a medium density residential subdivision in Stafford County, Virginia.

Atlantic with uniform lot sizes and shapes, and generous front setbacks. The streets were 34 and 26 feet wide, numerous cul-de-sacs were used as turnarounds, and sidewalks were generally installed on both sides of the street. With the exception of a small tot-lot, the majority of the open space is unbuildable land, such as floodplains, steep slopes, wetlands, and stormwater management areas. Street runoff is conveyed by curb and gutter to a storm drain system that discharges to the intermittent stream channel. It then travels to a dry extended detention pond, which is primarily used to control flooding, but also provides limited removal of stormwater pollutants.

The open space design also results in 108 lots, but these were slightly smaller with an average size of 6,300 square feet. The design also incorporates many techniques of open space design as advocated by Arendt (1994). The design techniques employed in the redesigned site (Figure 4) include:

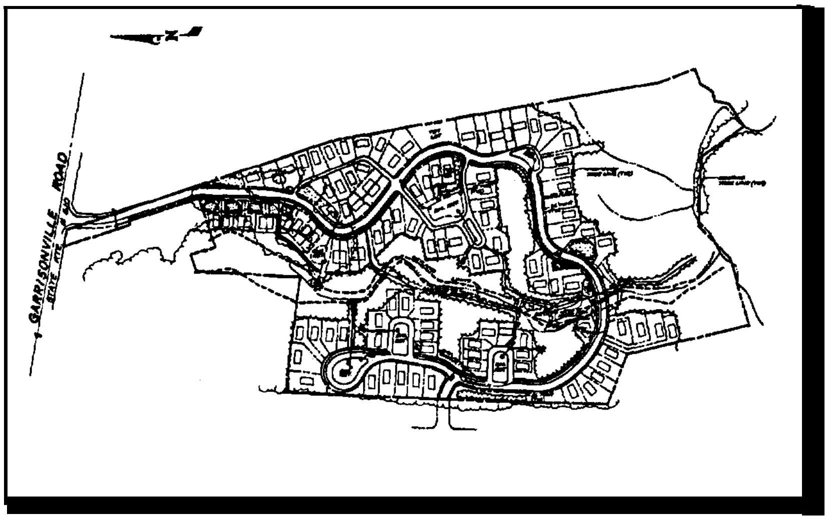

Figure 4. The open space design of Stonehill Estates.

- identify sensitive natural features, including mature forest and wetland, to be protected
- incorporate a minimum 1 00-foot buffer along all perennial and intermittent streams
- maximize the amount of community open space and preservation of natural areas
- maintain the same number of lots as the conventional design
- provide open space adjacent to as many lots as possible
- incorporate stormwater management attenuation and treatment throughout the site
- use narrower streets, loop roads, shorter driveways, and fewer sidewalks
- allow for irregular shaped lots and shared driveways
- manage stormwater in a "treatment train" with bioretention facilities that discharge to a small but more effective wet pond

The open space design resulted in reduced impervious cover, reduced stormwater runoff, increased stormwater infiltration, and reduced infrastructure cost over the medium density subdivision conventional design (Table 1).

The Benefits of Open Space Design

For both of these case studies, application of the open space design techniques resulted in reduced impervious cover, which translates directly to reduced stormwater runoff. Other "redesign" studies recently conducted in Delaware, Maryland, and Virginia have provided similar results. These combined results consistently demonstrate that better site design can reduce impervious cover by 25 to nearly 60% and stormwater runoff by 4 to over 60% for a range of subdivisions (Table 1).

Table 1. Redesign Analyses Comparing Impervious Cover and Stormwater Runoff from Conventional and Open Space Subdivisions

Residential Subdivision	Conventional Zoning for Subdivision	Impervious Cover at the Site			% Reduction in Stormwater Runoff
		Conventional Design	Open Space Design	Net Change	
Duck Crossing	3 - 5 acre lots	8%	5%	- 35%	23%
Stonehill Estates	1/3 acre lots	27%	21%	- 24%	24%
Remlik Hall [1]	5 acre lots	5.4 %	3.7%	-31%	20%
Tharpe Knoll [2]	1 acre lots	13%	7%	- 46%	4%
Chapel Run [2]	½ acre lots	29%	17%	-41%	31%
Pleasant Hill [2]	½ acre lots	26%	11%	- 58%	54%
Prairie Crossing [3]	½ - 1/3 acre lots	20%	18%	- 20%	66%
Buckingham Greene [2]	1 /8 acre lots	23%	21%	- 7%	8%
Belle-Hall [4]	High Density	35%	20%	- 43%	31%

sources: [1] Maurer, 1996; [2] DE DNREC, 1997; [3] Dreher, 1994; and [4] SCCCL, 1995.

For both Duck Crossing and Stonehill Estates, the conventional design results in the highest annual volume of runoff and the lowest volume of infiltration, as was expected. Of particular interest is the fact that the controlled conventional design results in a higher annual runoff volume and a lower infiltration rate than the uncontrolled open space design. This, however, should not imply that better site design alone, without structural stormwater management, is sufficient in controlling stormwater runoff from this site since the open space designs do not come close to replicating pre-developed hydrology.

Less impervious cover and stormwater runoff, in turn, translates directly to smaller pollutant loads. Reducing the impervious cover, preserving natural areas, and providing multiple stormwater practices in series reduced nutrient export for both case studies. However, neither open space design meets pre-development nutrient loads.

One area of particular interest for Duck Crossing is the implication of on-site sewage disposal systems. The conventional design included astandard septictankand field for each lot, which resulted in phosphorus and nitrogen loads that far exceeded pre-development levels. Recirculating sand filters were used in the open space design, instead of conventional septic systems, because they yield better nitrogen removal efficiencies and are actually less expensive to construct. This resulted in a much lower nutrient output from the entire site. However, even in the open space design, the septic systems are the predominant source of nutrients.

For both case studies, the total infrastructure costs include the sum of the estimated costs of stormwater management, storm drainage, paving, sidewalk, curb and gutter, landscaping and reforestation, water, sewer and septic systems. In both cases, the open space design resulted in a cost savings. Costs associated with grading, erosion and sediment control, building construction and other incidental costs associated with land development were not analyzed. In general, these costs should be comparable between the two development options. If anything, the grading and erosion and sediment control costs should be lower with the open space design since less land is disturbed.

Several other studies have also shown that open space development can be significantly less expensive to build than conventional subdivision developments. Most of the cost savings are due to savings in road building and stormwater management conveyance costs. The use of open space design techniques at a residential development in Davis, California provided an estimated infrastructure construction costs savings of $800 per home (Liptan and Brown, 1996). Other examples demonstrate infrastructure costs savings ranging from 11 to 66%. Table 2 lists some of the projected construction cost savings generated by the use of open space redesign at several residential sites.

Table 2. Projected Construction Cost Savings for Open Space Designs from Redesign Analyses

Residential Subdivision	% Construction Savings	Notes
Duck Crossing	12%	Includes roads, stormwater management, and reforestation
Stonehill Estates	20%	Includes roads, stormwater management, and reforestation
Remlik Hall [1]	52%	Includes costs for engineering, road construction, and obtaining water and sewer permits
Tharpe Knoll [2]	56%	Includes roads and stormwater management
Chapel Run [2]	64%	Includes roads, stormwater management, and reforestation
Pleasant Hill [2]	43%	Includes roads, stormwater management, and reforestation
Buckingham Greene [2]	63%	Includes roads and stormwater management

Sources:' Maurer, 1996; [2] DE DNREC, 1997.

Implications for the Watershed Manager

Better site design reduces impervious cover, conserves larger contiguous natural areas, and incorporates more advanced stormwater treatment, which results in reduced stormwater runoff, increased infiltration, and reduced nutrient export. Hopefully, the results of this study, as well as other redesign analyses, will answer some of the questions of local governments, consultants, and developers as to the benefits of better site design.

However, there may still be difficulties to overcome before better site design becomes a reality and common practice in many communities. Once there is a willingness to incorporate better site design techniques into new developments, many communities may find that their existing development codes and ordinances are in conflict with the goals of better site design. For example, many local codes and ordinances require excessive impervious cover in the form of wide streets, expansive parking lots, and large-lot subdivisions. In addition, there are generally few, if any, incentives or requirements for developers to conserve natural areas. When obstacles to better site design are present, it is a sign that a community may want to reevaluate and consider changing some of its local codes and ordinances.

In 1997, CWP convened a national site planning roundtable to address this very issue. During the 18-month consensus-building process, a diverse cross section of national planning, environmental, home builder, fire and safety, and public works organizations (as well as local planning officials) crafted 22 model development principles to help further better site design at the local level. This national roundtable is serving as a model for local government implementation of better site design principles.

Recently, Frederick County, Maryland, initiated a local roundtable to take a critical look at its own development rules. Members of the development community in partnership with local planning and zoning and public works staff are meeting to identify and overcome impediments to better site design that are embedded in the county's codes and ordinances. The outcome of the consensus process should be development rules that encourage rather than discourage the application of better site design techniques.

Changing local development rules is not easy. Progress toward better site development will require more and more local governments to examine their current practices in the context of a broad range of concerns, such as how changes will affect development costs, local liability, property values, public safety, and a host of other factors. Advocates of better site design will have to answer some difficult questions from fire chiefs, lawyers, traffic engineers, developers, and many others in the community. Will a proposed change make it more difficult to park? Lengthen response times for emergency vehicles? Increase risks to the community's children? True change occurs only when the community addresses these and other questions to the satisfaction of all interests.

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Predicting Erosion Rates on Construction Sites Using the Universal Soil Loss Equation in Dane County, Wisconsin

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Abstract

The Universal Soil Loss Equation (USLE) was developed for estimating sheet and rill erosion from agricultural fields under specific conditions. Parameters used to estimate erosion include rainfall energy, soil erodibility, slope length, steepness, surface cover, and management practices. Traditionally, urban conservation planners have not used the USLE for estimating soil loss and evaluating conservation measures and have relied on intuition alone to locate erosion control practices on constructions sites. The results of this process are often subjective and may vary with the skill of the planner. A USLE-based equation would provide a valuable, objective method for all planners, regardless of skill, to tailor specific construction site practices to existing conditions. A method to predict soil loss from construction sites was developed by adapting existing data for USLE erosion calculations to construction site conditions. In addition, the construction site procedure was used to create a user-friendly computer-based program to assist planners in developing erosion control plans. The computer program was distributed to engineers responsible for erosion control planning in Dane County, Wisconsin. Implementation of the USLE-based equation has proven to be a valuable tool for assessing alternatives for site management and erosion control. Planners are able to uniformly implement the equation on construction sites throughout the county, decrease the time necessary to complete a USLE calculation, and reduce human error.

Keywords:

Universal Soil Loss Equation (USLE), urban erosion control.

Background

Soil erosion, detachment of soil particles from the soil surface, results when soil is exposed to the power of rainfall energy and flowing water. Soil erosion causes a loss of productivity in the land, delivers millions of tons of sediment into waterways, and provides a substrate for toxic chemicals which are carried into receiving waters. Construction site erosion has been identified as a significant source of suspended solids in runoff in many parts of the United States (Hagman, et al., 1980; Yorke and Herb, 1976; Becker, et al., 1974). In the State of Wisconsin, sediment is the largest pollutant by volume (Wisconsin Department of Natural Resources, 1994). When erosion is compared on a rate basis, construction site erosion generates more erosion in ashortperiod of time than any other land disturbing activity (Johnson and Juengst, 1997). While it is not possible to urbanize a watershed without exposing soil to erosive forces, it is possible to plan construction to control the production of sediment through the use of erosion prevention and reduction practices.

The Universal Soil Loss Equation (USLE) (Equation 1) was developed by the United States Department of Agriculture (USDA) for estimating sheet and rill erosion from agricultural fields under specific conditions (Wischmeier and Smith, 1978). The USLE enables planners to predict the average annual rate of soil erosion for combinations of seeding and management practices in association with a specified soil type, rainfall pattern, and topography. The equation groups interrelated physical and management parameters influencing erosion rate into six major factors whose site-specific values can be expressed numerically. More than a half century of erosion research in many states has supplied information from which the USLE factors were determined.

The Universal Soil Loss Equation.

$$A = R \times K \times (LS) \times C \times P \qquad \text{(Equation 1)}$$

Where:

A = average annual soil loss
R = rainfall and runoff factor
K = soil erodibility factor
L = slope length
S = steepness factor
C = cover and management factor
P = support practice factor

A The computed soil loss in tons/acre/year.

R The rainfall and runoff factor is the number of erosion-index units in an average year's rain. The erosion index is the storm energy in hundreds of foot tons times the 30 minute storm intensity.

K The soil erodibility factor is the soil loss rate (tons per acre) of a specific soil type and horizon as measured on a standard plot of land.

L The slope/length factor is the ratio of soil loss from the actual land slope length to that from a standard plot (726 feet in length) of land. Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff water enters a well defined channel that may be part of a drainage network or a constructed structure.

S The slope/steepness factor is the ratio of soil loss from the actual land slope gradient to that from a standard plot of land (9%).

C The cover and management factor is the ratio of soil loss from an area with specified cover and management to the corresponding loss from a clean-tilled, continuously fallow condition.

P The ratio of soil loss with a support practice such as contouring, stripcropping, or implementing terraces compared to up and down the slope cultivation. The support practice factor does not usually apply to soil loss on construction sites.

Soil losses computed with the USLE are best available estimates, not absolutes. The USLE will generally be most accurate for medium-textured soils, slope lengths of less than 400 feet, gradients of 3 to 18%, and consistent seeding and management systems represented in the USDA erosion studies. The USDA research shows that in comparing actual soil loss to computed soil loss, 84% of the differences in long-time average soil losses were less than 2 tons/acre/year (Wischmeier and Smith, 1978). The accuracy of a predicted soil loss depends on how accurately physical and management conditions on the particular site are described by the parameter values. Large-scale averaging of parameter values on mixed drainage areas reduces accuracy.

Traditionally, urban conservation planners have not widely used an equation similar to the USLE for estimating soil loss and evaluating conservation measures. They have relied on intuition alone to locate erosion control practices on construction sites. A USLE-based equation provides a valuable, objective method for all planners, regardless of skill, to tailor specific construction site practices to existing conditions. Erosion control is more efficient when it focuses erosion control practices in areas on the site identified by the USLE as being the most susceptible to erosion.

The objectives of this project were to: 1) develop a method to predict soil loss from construction sites by adapting existing data for USLE erosion estimation to construction site conditions and 2) create a user-friendly computer-based program to assist planners in developing construction site erosion control plans with the USLE.

Implementation Area

The project was conducted in Dane County, located in south-central Wisconsin. Dane County has extremely diverse and vast water resources with 475 miles of rivers and streams and 37 lakes, but these resources are threatened by rapid urban growth. Within the next twenty years, it is conservatively estimated that an additional 72,000 people will live in the county. Residents recognize how impacts to water quality affect their standard of living, and are interested in protecting water resources.

Due to the value that the citizens of Dane County place on water quality, a very restrictive erosion control ordinance was adopted in 1995. Any land disturbance greater than 4000 square feet must comply with the Dane County Erosion Control Ordinance (Dane County, 1999). As part of this ordinance, applicants must prove that the erosion rate on their project will not exceed 15 tons per acre over the construction period for non-sensitive areas. In sensitive areas, including sites adjacent to, or directly draining to, lakes, streams, and wetlands, the soil loss is limited to 7.5 tons per acre over the construction period. In order to prove the soil loss rate is below the county standard, applicants need to calculate the USLE for their site from the start of construction until the site is stabilized. The Dane County Land Conservation Department reviews erosion control plans for accuracy of the plan and compliance with the ordinance.

Methods

Adapting USLE to construction site conditions

Our first objective was to develop a method of predicting soil loss from erosion on construction sites based on the guidelines given by the USDA for the USLE. In order to adapt the USLE to urban conditions, each variable in the equation was examined (see Equation 1).

The rainfall factor, R, is the first factor modified. Published R values represent erosivity during an average year. Most construction sites do not remain disturbed for exactly one year. In addition, the time of year that the site is open is critical in determining the amount of rainfall energy that will occur. In the Midwest, over half of this rainfall energy occurs during July, August, and September. Projects that take place in the summer will experience higher intensity storms than projects constructed in the winter. For these reasons, the R factor needs to be adapted to the construction schedule of the project (Table 1).

Table 1. Percent of R occurring after January 1st for Dane County, Wisconsin.

	January	February	March	April	May	June
1st	0	0	2	4	9	20
15th	0	1	3	6	14	28
	July	August	September	October	November	December
1st	39	63	80	91	97	99
15th	59	72	87	94	98	100

Once the percent R is calculated for the interval of time that the land will be open, it is multiplied by the annual R factor for Dane County (150).

$$R = (\% \text{ of } R \text{ to date}) \times (\text{Annual } R \text{ factor})$$

The soil erodibility factor, K, represents a soil's ability to resist erosion. The factor is determined by documenting erosion of a soil in a bare condition on a unit test plot. The higher the erosion rate, the higher the K factor. On construction sites, the subsoil K factor is often used because the topsoil is usually stripped. Subsoil K factors can be found in USDA

Soil Interpretation Records. The soil properties that affect erodibility include: soil structure, soil particle size distribution, permeability, organic matter content, and iron content.

The slope length/steepness factor, LS, relates the length and steepness of the slope (Equation 2). The rate of erosion increases exponentially as the length of the slope becomes longer. Erosion rates rise even more drastically as the steepness of the slope increases. The percent slope is a representative portion of the disturbed area, representing overland flow, not channel flow. The slope length is measured along the flow path from the top to the bottom of the slope of the disturbed area.

Formula used to calculate the LS factor.

$$LS = (L/76.6)^{M}(65.41\,Sin^{2}\theta + 4.56\,Sin\theta + 0.065) \qquad \text{(Equation 2)}$$

Where: L = slope length in feet

6 = angle of slope (in degrees)
M = 0.2 for slopes < 1%
M = 0.3 for slopes 1 .O to 3.0%
M = 0.4 for slopes 3.0 to 4.5%
M = 0.5 for slopes > 4.5%

The cover and management factor, C, is based on the type and condition of the cover on the soil surface. In construction site erosion control, the cover is extremely important. The vegetative cover provides protection from rainfall impact and runoff water. If the condition of the cover is poor, the C factor will be high. Conversely, when the vegetation is well established, the erosion and C factor will be reduced. C factors for construction sites can be found in *Predicting Rainfall* Erosion Losses (Wischmeier and Smith, 1978). The C factors for seeding, seeding and mulching, and sod represent the average cover over the establishment period. Once the site is seeded or sod is installed, a period of sixty days during the growing season is automatically assumed for cover establishment. If the end of the sixty-day cover establishment period falls after the recommended seeding dates, the calculation must be carried out to the following spring to allow for adequate growth.

Commonly Used C Factors:	Bare ground	1 .00
	Seeding	0.40
	Seeding and Mulching	0.12
	Sod	0.01

The support practice factor, P, is not used to calculate soil loss on construction sites.

The product of the R, K, LS, and C factors equals the computed soil loss per acre over the construction period. In Dane County, if this number is greater than the required standard, the project must reduce erosion below the standard by using erosion control practices or by changing the management schedule. This assumes that 100% of soil loss is transported and deposited off-site for relatively small areas of less than 40 acres with no intervening obstructions or flattening of the land slope.

Developing the Spreadsheet to Calculate the USLE

Implementation of the USLE in erosion control plans was required for all land-disturbing activities greater than 20,000 square feet in Dane County after January, 1995. The calculation of soil loss was difficult for the consulting engineers responsible for submitting plans. In addition, the USLE calculations were often done incorrectly or the wrong data were used as inputs. For these reasons, a user-friendly computer-based program was developed to assist erosion control planners with the USLE calculation. The program uses Microsoft Excel 97*, a spreadsheet program that is commonly used among the engineering community.

The worksheet (Figure 1) uses the following variables and inputs (Table 2) which are either entered by the user or automatically calculated in the non-shaded rows.

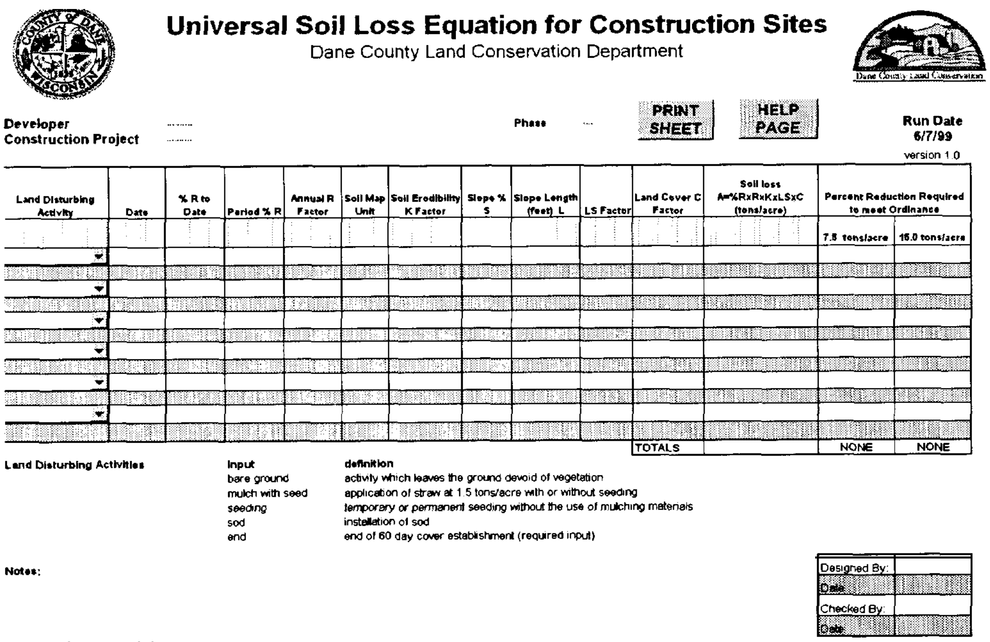

Figure 1. Screen-capture of spreadsheet.

Table 2. Variables used in the spreadsheet.

Column #	Variable	Type
1	Land Disturbing Activity	entered by user
2	Date	entered by user
3	% **R** to Date	automatically calculated
4	Period % **R**	automatically calculated
5	Annual **R** Factor	automatically calculated
6	Soil Map Unit	entered by user
7	Soil Erodibility K Factor	automatically determined
8	Slope % **S**	entered by user
9	Slope Length L	entered by user
10	LS Factor	automatically calculated
11	Land Cover C Factor	automatically determined
12	Soil Loss	automatically calculated
13	Percent Reduction to Meet Ordinance	automatically calculated

Variable/Input Descriptions:

Land- Disturbing Activity

The land-disturbing activity relates to the type of disturbance that is occurring on the ground and must be selected by using a pull down menu. Activity Inputs:

*Use of the commercial product name is for the convenience of the reader and does not imply endorsement of the product by either the Dane County Land Conservation Department or the University of Wisconsin.

bare ground	Usually the initial disturbance and occurs when the ground is left bare due to stripping vegetation, grading, or other actions that leave the ground devoid of vegetation.
seeding	The application of permanent ortemporaryseeding without the use of mulch. Seeding requires that the user allows 60-days during the growing season for cover establishment.
mulch with seed	The application of a minimum of 1.5 tons/acre straw or other comparable mulching. This input is entered if the seeding and mulching are done at the same time. It is not necessary to also enter *seeding* if this input is used. This input also requires a 60 day cover establishment period during the growing season.
sod	The installation of sod for cover establishment.
end	*End* is a required input at the end of the 60-day cover establishment period. If the site is stabilized by a method other than vegetative cover, *end* should also be entered.

Date

The date the planned land disturbing activity begins, e.g. 5/15/99. The activity is assumed to continue until the next activity is entered. When seeding dates are later than the dates recommended for permanent cover establishment, the *end* date must be carried out to the next spring, rather than 60 days.

% R to Date

The percentage of the annual R factor from January 1st to the entered date.

Period % R

The percentage of the annual R factor calculated for the period from one land disturbing activity to the next.

Annual R Factor

The rainfall factor, R, is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of a specific rainfall. In Dane County, Wisconsin the rainfall factor is 150.

Soil Map Unit

The soil map unit for the predominant soil type in the area of the land disturbing activity.

Soil Erodibility K Factor

The erosiveness factor of the subsoil for the specified soil map unit.

Slope % S

The percentage slope for the representative portion of the disturbed area, representing overland flow and not channel flow.

Slope Length L

Slope length (in feet) is measured along the overland flow path from the top to the bottom of the slope of the representative disturbed area.

LS Factor

The LS factor is calculated using the equation for LS described previously (see Equation 2).

Land Cover C factor

The cover and management factor is the ratio of soil loss from an area with a specified cover and management practice to that of a unit plot of bare land. The input for the land disturbing activity corresponds to this factor.

Soil Loss

The predicted value of soil loss (tons/acre) which corresponds to the time period of each land disturbing activity. This value is calculated using the equation:

$$A = \%R \times R \times K \times (LS) \times C$$

Percent Reduction Required to Meet Ordinance

The percentage value in the total row corresponds to the reduction of soil loss necessary to comply with the Dane County Erosion Control Ordinance. It is required that the cumulative soil loss rate not exceed 15 tons/acre for non-sensitive areas and 7.5 tons/acre for sites that are located adjacent to or directly drain to sensitive areas.

Typical Spreadsheet Example for Dane County, Wisconsin

Figure 2 shows a sample USLE calculation using the spreadsheet. The assumptions are that construction will begin on July 17, 1999, and the site will be seeded and mulched on October 31, 1999. The representative pre-existing slope is 10% *over* 100 feet and the slope after grading will be 5% over 250 feet. The soil type is Dresden Silt loam (DsC2). The estimated soil loss rate for this site is 15.9 tons/acre. If this site is located near a sensitive area, the soil loss must be reduced by 53% to comply with the 7.5 tons/acre standard; on the other hand, if the site was not located near a sensitive area, the soil loss only needs to be reduced by 6% (15 tons/acre standard).

Universal Soil Loss Equation for Construction Sites
Dane County Land Conservation Department

Developer Example Calculation
Construction Project -----
Phase —
PRINT SHEET | HELP PAGE
Run Date 7/7/99
version 1.0

Land Disturbing Activity	Date	% R to Date	Period % R	Annual R Factor	Soil Map Unit	Soil Erodibility K Factor	Slope % S	Slope Length (feet) L	LS Factor	Land Cover C Factor	*Soil loss* A=%RxRxKxLSxC (tons/acre)	Percent Reduction Required to meet Ordinance 7.5 tons/acre	15.0 tons/acre
bare ground	7/17/99	53.3%	26.2%	150	DsC2	0.28	10.0%	100	1.38	1.00	15.2		
	To												
mulch with seed	8/31/99	79.5%	17.3%	150	DsC2	0.28	5.0%	250	0.85	0.12	0.7		
	To												
end	10/31/99	96.8%	3.2%	150	DsC2	0.28	5.0%	250	0.85				
										TOTALS	15.9	53%	6%

Land Disturbing Activities

input	definition
bare ground	activity which leaves the ground devoid of vegetation
mulch with seed	application of straw at 1.5 tons/acre with or without seeding
seeding	temporary or permanent seeding without the use of mulching materials
sod	installation of sod
end	end of 60 day cover establishment (required input)

Notes:

Designed By:	
Date	
Checked By:	
Date	

Figure 2. Sample USLE calculation.

Results and Discussion

There are several advantages to using the adapted USLE for erosion control planning on construction sites. One advantage is being able to locate areas with the highest erosion rates, which results in more effective erosion control. If one portion of a construction site is predicted to have a higher erosion rate, more or larger erosion control practices may be targeted in that area, while less intensive practices may be required elsewhere on the site. The adapted USLE also facilitates the design of sediment ponds and other erosion control practices. The predicted amount of soil loss exceeding the standard can be used to calculate the percent reduction necessary to comply with the ordinance.

Another advantage is that the adapted USLE brings in the important element of time. In Wisconsin, the majority of the year's rainfall erosion occurs during the summer months. Summer is also the time of year that most construction is occurring. The USLE accounts for the date and duration the development project occurs and predicts the soil's vulnerability to erosion at that time. The USLE may show that staging the construction project will help to reduce the soil loss on the site.

The spreadsheet program has proven to be a valuable tool for calculating the soil loss. The program has been distributed for more than a year, free of charge, to the planners and consultants in Dane County. The County's review of the calculation in the erosion control plans has become easier and quicker by having a printout that summarizes the variables used. An advantage of having tables and formulas included in the spreadsheet, is the consistency that is achieved by everyone using the same parameters. Not only have the calculations of soil loss been more precise and time schedules more realistic, but planners and consultants have stated that it has saved them time and simplified the calculation process.

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Public Involvement Programs That Support Water Quality Management

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The Rouge River, a tributary to the Detroit River, in southeast Michigan, has been documented as a significant source of pollution to the Great Lakes System. The Rouge River Watershed spans approximately 438 square miles in 48 communities and three counties and is home to over 1.5 million residents. The eastern portion of the watershed contains much of the older, industrial areas of Detroit and Dearborn. The western and northern portions contains newer suburban communities and areas under heavy development pressure.

This paper discusses the programs used by the Public Involvement Team of Wayne County's Rouge River National Wet Weather Demonstration Project (Rouge Project) to (1) increase watershed awareness of Rouge River Watershed residents and business owners, (2) educate them about pollution sources to the Rouge River and (3) involve them in restoration of the Rouge River by showing them that small changes in their daily activities can help improve water quality and restore the river.

The Rouge Friendly Neighborhood Program was piloted over a two year period in watershed neighborhoods in three distinctly different areas of the watershed. All neighborhoods were surveyed to determine the initial level of knowledge about water quality issues, lawn care maintenance, and pollution prevention practices. Survey results were used to fashion a neighborhood program for each area. All three neighborhoods received Rouge Friendly brochures, newsletter articles, and other materials.

The Rouge Friendly Business Program, a companion program to the neighborhood effort, sought to educate small-to-mid-sized businesses about how they can positively impact the Rouge River by making small changes to daily business practices. Since auto-related businesses are very common in the Rouge River Watershed, an automotive services roundtable was convened. The partners included representatives of automotive service associations, the local chamber of commerce, and businessmen who met periodically for a year to review draft materials, make suggestions about the program's promotion, and to help mold the program before it was implemented. Once implemented, the industry representatives promoted the program in their publications and recruited businesses to participate in the program.

This paper will describe both of these pollution prevention programs and discuss how the Brightmoor neighborhood in the Rouge River Watershed was impacted by the Rouge Friendly Neighborhood and the Rouge Friendly Business Programs.

The Rouge Friendly Neighborhood Program

The Rouge Friendly Neighborhood Program was designed to be carried out by responsible neighborhood organizations. Preferred prerequisites were:

1. The group participating in the program must represent a defined area or neighborhood.

2. The group would participate in the Friends of the Rouge River Watch Program. The river system need not pass directly through the neighborhood for participation. An assigned segment could be identified for the group by Friends of the Rouge.

3. The group would participate in the Friends of the Rouge Storm Drain Stenciling Program. The stenciling of storm drains should include, but is not limited to, all the storm drains within their designated neighborhood or area.

4. The group should actively participate and/or encourage proper household hazardous waste management. This could occur through:

   - Reduced purchasing of hazardous house chemicals
   - Proper use of household hazardous chemicals
   - Proper disposal of hazardous household chemicals
   - Use of less-toxic alternatives to household hazardous chemicals

   The group can accomplish this requirement by distributing information concerning proper household hazardous waste management to their designated neighborhood.

5. The group would facilitate education of residents regarding non-point source pollution. Information would be provided by the Rouge Project Team for distribution to the designated neighborhoods.

6. Submittal of semi-annual reports discussing the activities that have been taking place could be a requirement to maintain Rouge Friendly Neighborhood status.

Three Rouge Project area neighborhoods representing different demographics and development history were chosen as pilots for the Rouge Friendly Neighborhood Program. They were the (1) Brightmoor area of Detroit, an older, developed area of the watershed along the Main Branch of the Rouge River; (2) Golfview Manor subdivision in Dearborn Heights, a newer subdivision along the Middle Branch of the Rouge River; and (3) West Bloomfield Place, a subdivision in West Bloomfield Township, a developing area along the Upper Branch of the Rouge River. These three pilots represented communities with diverse demographics and concerns.

The Brightmoor neighborhood was a deteriorating area with strong community activism regarding neighborhood problems and concerns. The neighborhood also showed strong stewardship for the Rouge River, which serves as a western boundary to the neighborhood and flows through a nearby park. Golfview Manor in Dearborn Heights was a more upscale, manicured neighborhood that was very active through its subdivision association, but did not have a real connection to the River. West Bloomfield Place in West Bloomfield Township was an upper income, less urban area bounded by a wetland.

Meetings were held with a core group of representatives from each neighborhood to garner support from the neighborhoods' leadership and to discuss what the program was and what the expected outcomes were.

The residents of all three pilot areas were sent a survey, distributed by mail or door-to-door, to document their knowledge of Rouge River water quality, storm water issues, and household hazardous waste disposal. In addition, respondents were asked for demographic information. The survey information was used to determine what the Rouge Friendly Neighborhood Program should focus on in each particular neighborhood.

Educational materials that had been developed about storm water pollution, household hazardous waste (and its disposal), and watershed awareness were reviewed by each group. Each core group helped develop the particular program that would be implemented in their neighborhood, because Rouge Project staff knew that no program would be a success without the core groups' support and endorsement. These core group members were relied on to explain the program at neighborhood meetings.

The Rouge Friendly Business Program

The Rouge Friendly Business Program was developed as a partnership between Wayne County, local government, and the business community to restore and protect the Rouge River. To accomplish this goal, information and assistance are provided to small business owners to teach them how they can positively affect the water quality of the Rouge River by changing some of their everyday practices. The education process is not about major contaminants, but those little things that slip the mind, such as keeping the dumpster lid closed and storing materials under cover. These simple actions can affect water quality because they stop pollutants from entering the storm system. As an incentive to participate, Wayne County embraced the concept that businesses in the watershed that demonstrate stewardship and a strong environmental ethic should be recognized by the community for their voluntary participation. As such, these businesses should enjoy greater name recognition through the efforts of the local and regional media as well as specific program materials, such as decals and magnets that identify the business as Rouge Friendly.

The Rouge River Watershed has approximately 42,000 businesses in its 48 communities and three counties. To design program materials that would have the greatest impact, three criteria were developed to target business types. They are:

- The business has a high incidence of illicit connections to storm drains
- The business conducts a significant number of pollutant-generating activities outdoors
- The business is found in large numbers in the watershed

Using these criteria, six types of businesses were selected and specific activities identified. They are:

- Vehicle Service Industry
- Food producers, grocers, and eating establishments
- Metal Machining
- Earth Disturbing Construction
- Remodeling and Repair Contractors
- General Business

Pollution control criteria were established for each kind of business. These criteria were used to create a self-assessment form to be used by business owners to evaluate how “Rouge Friendly” their businesses are. Best Management Practices (BMPs) were also written that correspond to each activity and this information was put into the booklet along with a self-assessment form for distribution.

Representatives of various trade organizations were invited to participate in a Vehicle Service Industry Roundtable. The roundtable was asked to review and comment on the educational materials, the self-assessment form, the BMPs, and the best way to conduct program outreach. Rouge Project staff sought to engage businesses in an ongoing dialogue to determine what approach would work best, with a secondary goal of determining how to get businesses to participate. Feedback from this group resulted in a name change from the “Clean Business Program” to the “Rouge Friendly Business Program.” This was not a quick process, but took approximately six months of meetings to (1) form a Vehicle Service Industry roundtable, (2) explain the purpose of the Rouge Friendly Business Program, and (3) refine the program and products. The Rouge Friendly Business Program elements were finalized as follows:

- Self-assessment form and action plan
- Best Management Practices

- Site visits by technical staff
- Recognition materials for participating businesses (stickers and magnets)
- Business pledge and newspaper recognition

After these materials were finalized, Wayne County and Rouge Project staff promoted the Rouge Friendly Business on a pilot basis and recruited businesses through the following mechanisms:

- Business Roundtable contacts
- Letter and telephone contacts
- Door to door contact with businesses
- Contact through homeowner/neighborhood associations
- Integration of Business and Residential Programs

By the end of the pilot period, the Wayne County Department of Environment had recognized 20 businesses as Rouge Friendly.

The Brightmoor Community Pilot

The Brighmoor area of Detroit was developed in the 1920s as a neighborhood forworking-class families. Most houses are frame, with the newer areas of the neighborhood (1940s and 1950s) of brick construction. Over the past 15 years, the Brightmoor area has deteriorated. Its once vibrant business strip is dotted with boarded, vacant buildings, graffiti, trash, and debris. Whole blocks of residential land are vacant and overgrown and illegal dumping is abundant. Environmental abuses ranged from a myriad of abandoned vehicles to illegal car repair businesses on residential streets. The Rouge Friendly Neighborhood Survey (Attachment A), distributed in Brightmoor in 1996, showed that the top two environmental concerns in the area were illegal dumping and abandoned housing.

Despite these challenges, the Brightmoor neighborhood had two characteristics that made it a viable pilot for the Rouge-Friendly Programs. One, Eliza Howell Park, located on its western edge, was traversed by two branches of the Rouge River. Second, Brightmoor had a wealth of grassroots organizations who were working to make the neighborhood better. Some annually removed log jams and other debris from the Rouge River in Eliza Howell Park during Rouge Rescue, sponsored by Friends of the Rouge, a grassroots organization serving the whole watershed.

Initial contact was made with the Brightmoor Concerned Citizens and other neighborhood representatives in January, 1996. The group agreed that they would like to participate as a Rouge Friendly Neighborhood pilot. A month later, the same group met again with Rouge Project staff. This time, city parks staff were present. They were told about the possibility of grant funding for storm water projects by the Rouge Project. The group brainstormed the kinds of things they would like to see happen at the park, which had suffered from spotty maintenance. They agreed that they would like to see wildflowers and prairie grass planted, nature trails restored, and a community garden created. The parks department later applied for and was awarded a $180,000 grant to plant wildflowers and prairie grasses and to install nature trails in the lower end of the park, near the Rouge River.

The next step in the program was to survey residents about their knowledge of pollution entering the river and household hazardous waste disposal, their neighborhood environmental concerns, and demographic information. The survey was created with input by the core neighborhood group. The major data extracted from the survey were:

- 78% thought the Rouge River was polluted or very polluted, and 20% thought the river was getting worse.
- 38% did not know that the storm drains lead directly to the Rouge River. However, 56% understood that sanitary sewers go to the wastewater treatment plant.

- 18% correctly answered that industry pollutes the Rouge River the least and 66% thought stormwater pollutes the least.
- 87% maintained their own lawn. There was an even distribution among those who never fertilize their lawns and those who fertilize l-2 times per year.
- 75% did not change their own motor oil.
- 80% took their cars to a car wash instead of washing it themselves.
- 92% claimed indicated that they know what household hazardous waste is, and 73% correctly identified motor oil as a household hazardous waste. However, 54% did not properly dispose of their wastes.
- 83% said they were committed/very committed to make small changes to prevent pollution.

Following are neighborhood issues, in order of importance:

1. Abandoned buildlings
2. Illegal dumping
3. Household hazardous material disposal
4. Infrequency of street sweeping and storm drain cleaning
5. Recycling
6. Do-it-yourself car repair/illegal car lots on residential streets
7. Overuse of garden/lawn pesticides
8. Overuse of fertilizer
9. Composting

Wayne County Rouge Project staff, Friends of the Rouge, and Brightmoor Concerned Citizens leadership made a presentation, including survey results, to the general membership in May, 1996. The general membership was enthusiastic about the program. The annual Rouge Rescue held in Eliza Howell Park on June **1, 1996,** was expanded to include other activities, including storm drain stenciling, a tour of a newly constructed combined sewer overflow basin, and children's games.

Subsequent meetings with the Brightmoor group were used to brainstorm what the specific program elements should be and what outcomes were expected. The following elements were supported by the core group:

- Urban gardens on vacant lots
- Composting education
- Attempting to get rid of the massive log jam at the confluence of the Upper and Main Rouge River in Eliza Howell Park
- A tour of the area for the Detroit Environmental Court judge
- Lawn signs that read "I support the Rouge Friendly Neighborhood Program"
- Early recognition of well-maintained lawns and gardens; Brightmoor's "Resident of the Month"

- A Brightmoor Rouge-Friendly Business Program
- A renters' workshop to educate tenants about their rights and responsibilities and the responsibilities of landlords
- Educational materials in the various neighborhood newsletters

All of the activities were implemented except the lawn signs, the recognition of well-maintained gardens, and the renters'workshop. By the fall of 1996, the focus had shifted to conducting a monthly combined resident/business owners' meeting to include businesses, which were primarily vehicle service oriented, into the Rouge-Friendly initiative.

Results and Outcomes

Rouge-Friendly Neighborhood Program: Because of the enthusiasm and commitment of Brightmoor residents and business owners, many activities were conducted. They were:

- Thousands of educational brochures and children's materials were distributed in community centers, businesses, schools, and newsletters.
- A local business owner successfully sued a public utility that was pumping hundreds of gallons of polluted stormwater into the Rouge River.
- The local community organization not only enthusiastically participated in the annual Rouge Rescue event, but conducted another such event on its own.
- Through a partnership with the city parks department, the Greening of Detroit, and the Brightmoor Concerned Citizens, 100 trees were planted in Eliza Howell park by 200 local elementary school students.
- City officials agreed to conduct an environmental ticket blitz in the neighborhood, which resulted in the following tickets being written: 179 parking tickets, 71 abandoned cars tagged for removal, 8 stolen cars being towed, 15 public works tickets for bulk garbage being put at the curb too early, 2 environmental protection tickets, and 47 tickets for inoperable vehicles.
- A monthly meeting that included neighborhood residents, business owners, non-profit organizations, city officials (including police commanders), and county officials focused on environmental issues.

Rouge-Friendly Business Program: While many outstanding initiatives were accomplished by meeting with the Brightmoor stakeholders monthly, only one Brightmoor business was recognized as Rouge Friendly after ten months of monthly meetings. The meetings were well-attended and business owners felt comfortable discussing their environmental concerns. In June, of 1997, the approach for recruiting Brightmoor businesses as Rouge Friendly was changed. A community leader was paired with a technical staff member and they proceeded to visit neighborhood businesses. They visited 14 neighborhood businesses several times over a two-month period. Information about the program was left with the business owners, as well as an offer from the technical staff member to help the business owner with the self-assessment form. Through this effort, Wayne County recognized six additional Brightmoor businesses as Rouge-Friendly. This was a successful (43% participation), but labor intensive, method of recruiting businesses.

ATTACHMENT A

ME ROUGE RIVER PROJECT
A WORLD CLASS EFFORT
BRINGING OUR RIVER BACK TO LIFE

Are you willing to **prevent pollution** in your **neighborhood**?

Start today by filling out this questionnaire.

We are working with the Rouge River National Wet Weather Demonstration **Project** to make our subdivision a more attractive place to live. We have been chosen as one of three pilot neighborhoods in the Rouge River Watersheds to participate in a pollution prevention program that may be used as a model for other urban watersheds across the country. In order to design a program that best fits our needs, we need you to answer a few questions. The following survey is voluntary and **confidential.** Use the enclosed pre-stamped envelope to return the questionnaire by April 22, 1996.

		Very polluted		*Somewhat polluted*		*Not* polluted
1.	Do you think the Rouge River **is** polluted?	5	4	3	2	1
		Getting cleaner		***Staying** the same*		*Getting worse*
2.	Do you think the Rouge River Is getting **cleaner,staying** the same, or getting worse?	5	4	3	2	1

3. Where does water go when it enters an outside storm drain in your neighborhood?
   - ☐ To a storage tank under the ground
   - ☐ To the Rouge River
   - ☐ To the waste water treatment plant
   - ☐ Don't know

4. Where does water go when it is flushed down the toilet or sink?
   - ☐ To a storage tank under the ground
   - ☐ To the **Rouge** River
   - ☐ To the waste water treatment plant
   - ☐ Don't know

5. What pollutes the Rouge River the LEAST?
   - ☐ Combined sewer overflows (a *mixture of sewage and **stormwater that** flows into the **river** when* it *rains.)*
   - ☐ Stormwater *(water that runs **off** the grvund and **enters** the **river)***
   - ☐ Industry

6. How do you maintain your lawn?
   - ☐ Paid professional company
   - ☐ Paid neighbor
   - ☐ Someone in the household maintains it

7. How often is your lawn fertilized?
   - ☐ 1 **to 2 times per year**
   - ☐ *3* to 4 times per year
   - ☐ More than 4 times per year
   - ☐ Never

a. Where do you change the oil in your car?
   - ☐ Auto Repair Shop/Quick Oil Chnage
   - ☐ Yard ☐ Street ☐ Driveway

9. Do you usually wash your car or take it to a car wash?
   - ☐ Wash it myself
   - ☐ Carwash

10. If you change your oil at home, how do you dispose of it?
   - ☐ In the garbage
   - ☐ In the sewer
   - ☐ Don't know
   - ☐ On the ground
   - ☐ Take to facility that accepts used oil

11. Do you know what household hazardous materials are?
   - ☐ Yes
   - ☐ **No**

12. Which of the following is a household hazardous material?
   - ☐ **Baking** soda
   - ☐ Motor Oil
   - ☐ Lemon oil
   - ☐ Vinegar

13. **How do you dispose of your household's hazardous materials?**

- ☐ Put it in the trash
- ☐ Dump it down the sink
- ☐ Dump it on the ground
- ☐ Don't know
- ☐ Take it to a Household Hazardous Drop-off Area

14. **Indicate whether the following *environmental* issues are very important, important, or not important to your subdivision.**

	Very important		*Important*		*Not important*
Overuse of fertilizer	5	4	3	2	1
Composting	5	4	3	2	1
Abandoned buildings	5	4	3	2	1
Frequency of street sweeping and storm drain cleaning	5	4	3	2	1
Overuse of garden/lawn pesticides	5	4	3	2	1
Recycling	5	4	3	2	1
Household hazardous waste	5	4	3	2	1
Illegal dumping	5	4	3	2	1
Do-it-yourself car repair / Illegal car lots on residential streets	5	4	3	2	1
Other (specify:)________	5	4	3	2	1

15. **You can make small changes to prevent pollution (i.e. the type of fertilizer you purchase, how you dispose of your motor oil, etc.). What is your level of commitment to make these changes?**

Very committed		*Somewhat committed*		*Not interested*
5	4	3	2	1

16. **How many people, including yourself, live at this address?**

- ☐ 1
- ☐
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ More than 6

17. **How many of these are children?**

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ More than 4

18. **How many pets do you *own?***

- ☐
- ☐ 0
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ More than 4

19. **What is your gender?**

- ☐ Female
- • : Male

20. **What is your age group?**

- ☐ Under 18 years
- ☐ 18–30 years
- ☐ 3 145 years
- ☐ 46-60 years
- ☐ Above 60 years

21. **What was the last grade you completed in school?**

- ☐ Some high school
- ☐ Completed high school
- ☐ Post-high school training
- ☐ Some college
- ☐ Completed college
- ☐ Graduate or professional school

Thank you **for** doing your part in cleaning up **our subdivision!** **Remember,** return **the questionnaire in the pre-paid envelope by** April 22, 1996.
Any questions should go to John or Shelley Mlynarczyk at 533-3453

The Water-Wise Gardener Program: Teaching Nutrient Management to Homeowners

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Introduction

The Water-wise Gardener program was developed by Virginia Cooperative Extension (VCE) seven years ago with funding from the Cooperative State Research, Education, and Extension Service (CSREES) of the U.S. Department of Agriculture (USDA). It is an educational program aimed at reducing non-point source pollution from suburban residential areas. The educational focus is upon nutrients, especially nitrogen and phosphorus from lawn fertilizer over-application or misuse. The program seeks to reduce such nutrient pollution to Virginia waterways, and eventually the Chesapeake Bay, through the recruitment of homeowner participants from impaired watersheds. Participating homeowners attend educational seminars on lawn best management practices, are partnered with a Master Gardener volunteer, and are expected to keep accurate records and implement recommended practices. The program, which is currently being implemented in 12 urban/suburban Virginia counties, is supported by a combination of local county funds, grants from the Virginia Water Quality Improvement Act, and funds from USDA. Cooperative Extension Units in North and South Carolina have replicated the program.

How the Program Works

The Water-wise Gardener program begins by recruiting homeowners from watersheds with impaired streams or other identified problems to participate in a year-long lawn care educational program. The most successful recruitment method to-date has been to conduct a “reverse search” on the Internet by street name. Once names and addresses are identified, a recruitment letter is sent personalized for the watershed; e.g., “Dear Resident of the Bull Run Watershed.” The letter invites the homeowner to participate in the program and lists the benefits of participation, such as free seasonal seminars with regional experts, visits from a Master Gardener (volunteers trained by VCE in various aspects of horticulture), a free soil test, and Virginia Tech publications. In order to be enrolled in the program, the homeowners must return a completed pre-survey and a signed agreement form that details their obligation to the program. The pre-survey asks questions about their lawn care practices and attitudes before program involvement, as well as demographic information such as race, gender, income, and education levels. A stamped, self-addressed envelope is included for ease of return. For every 100 letters sent out, between 20-30 are typically returned. A simple database program keeps track of participants and their lawn care data. A reporting system on the Virginia Tech lntranet is currently being designed to record this information on a statewide basis by hydrologic unit.

Once enrolled, participants are assigned a personal Master Gardener. The Master Gardener schedules a visit with the homeowner to discuss his or her lawn. All Master Gardeners are instructed to stay outside on the lawn and not to go inside anyone’s home. Some choose to bring along a spouse, friend, or another Master Gardener. At this visit, the Master Gardener works with the homeowner to correctly measure the square footage of lawn area, determine the type and variety of grass, collect a soil sample, and ascertain previous fertilization practices and amounts previously applied, if known. This information forms the basis of a personalized lawn care plan for the homeowner. Master Gardeners also answer other questions the participant may have; common questions include weed and pest identification, what plant grows best where, and why certain plants are not thriving. The Master Gardener leaves a business card with a phone number or e-mail where he or she can be reached for further questions throughout the program year. All Master Gardeners receive 50 hours of classroom training as well as supplemental field training before being assigned to homeowners. Typically, a Master Gardener will be assigned to between 5-l 0 homeowners.

In addition to the one-on-one visits from Master Gardeners, homeowners attend seasonal seminars on timely topics of interest to those with lawns. In Northern Virginia, where cool-season grasses like Fescue and Bluegrass predominate, fall topics include soil testing, fertilization, core aeration, and over seeding. Spring topics include mowing and pruning, integrated pest management, and proper watering and planting. Popular locations for seminars include parks with covered pavilions, school auditoriums, county buildings, and libraries. Any easily accessible public location large enough to hold 50 to 100 people comfortably, and accessible to wheel chairs, will work. If held inside, cold temperatures, rain, or wind are not a problem; however, an outside area for demonstration purposes is essential. State and regional Cooperative Extension experts are recruited for the seminars to answer questions. Master Gardeners are also present, with various displays, to answer questions and to meet with their assigned participants.

A professional-quality newsletter is sent to all participants approximately six times per year. A grant-paid editor solicits articles that reinforce or complement topics taught at the seminars. Articles on various aspects of watershed management are also introduced. The newsletter is made available electronically to other Extension Agents for editing and reproduction elsewhere.

After participants have attended fall and spring seminars, they are visited again by their Master Gardener to collect final lawn data and conduct a post-survey of practices and attitudes. The most important piece of data collected is the amount of fertilizer now being applied. Square footage of turf can be re-checked, if needed, and questions answered.

The homeowner may chose to participate again the following year, or to offer their lawn as a demonstration lawn, and erect a sign in their yard to promote the program in the community. The post-surveys and data sheets are collected from all participants annually. Results are compiled and analyzed by a grant-paid technician and a final report generated for each Cooperative Extension unit as well as an overall report for statewide efforts.

Results

Data for the period March 1998 to June 1999 for the Virginia counties of Arlington, Loudoun, and Prince William shows 326 individual homeowner participants. These 326 homeowners managed 57.1 acres of turf in 11 different hydrologic units in the Northern Virginia area. Between 100-200 additional individuals attended seminars but did not participate in the pre- and post-survey and data collection.

Accurate information on amounts of nitrogen and phosphorus applied by participants before program involvement is difficult to get. Most did not remember how much fertilizer they had applied in the previous year. Many stated the reason they joined the program was in order to understand how much fertilizer to apply. A total of 72 participants reported pre-program fertilizer application of 1,062 pounds of nitrogen. The same 72 participants reported 762 pounds of nitrogen applied after program involvement, or a reduction of 300 pounds. Information on pre- and post-phosphorus was not collected.

Pre-surveys indicated that only 12% of all participants had soil tested for their lawns prior to applying fertilizer. Homeowners not testing soil are more likely to apply excess fertilizer. For this reason, Virginia Tech recommends soil testing as a nutrient management practice for home lawns. Post surveys show 95% of participants returning surveys tested soils after program involvement. Another important nutrient management practice for homeowners with cool-season turf is to fertilize in the fall, when uptake by roots occurs best. Pre-surveys indicated that only 32% were fertilizing at this time of year, while post surveys indicated that 64% were fertilizing in the fall. Similar increases were also observed for recommended practices such as aeration (from 34% to 83%), and over-seeding (from 35% to 76%). An increase in the number of participants not watering the lawn at all in the summer also increased (from 18% to 44%) (Figure 1).

Demographics from the program indicate that 72% of participants were male and 28% female. Participants were overwhelmingly white (89%); followed by black (7%), Asian (4%), and Hispanic (1%). The majority (42%) had a four-year college degree and a gross family income of over $70,000 a year (54%). More than one-third of the lawns were between 5,000 and 10,000 square feet (35%).

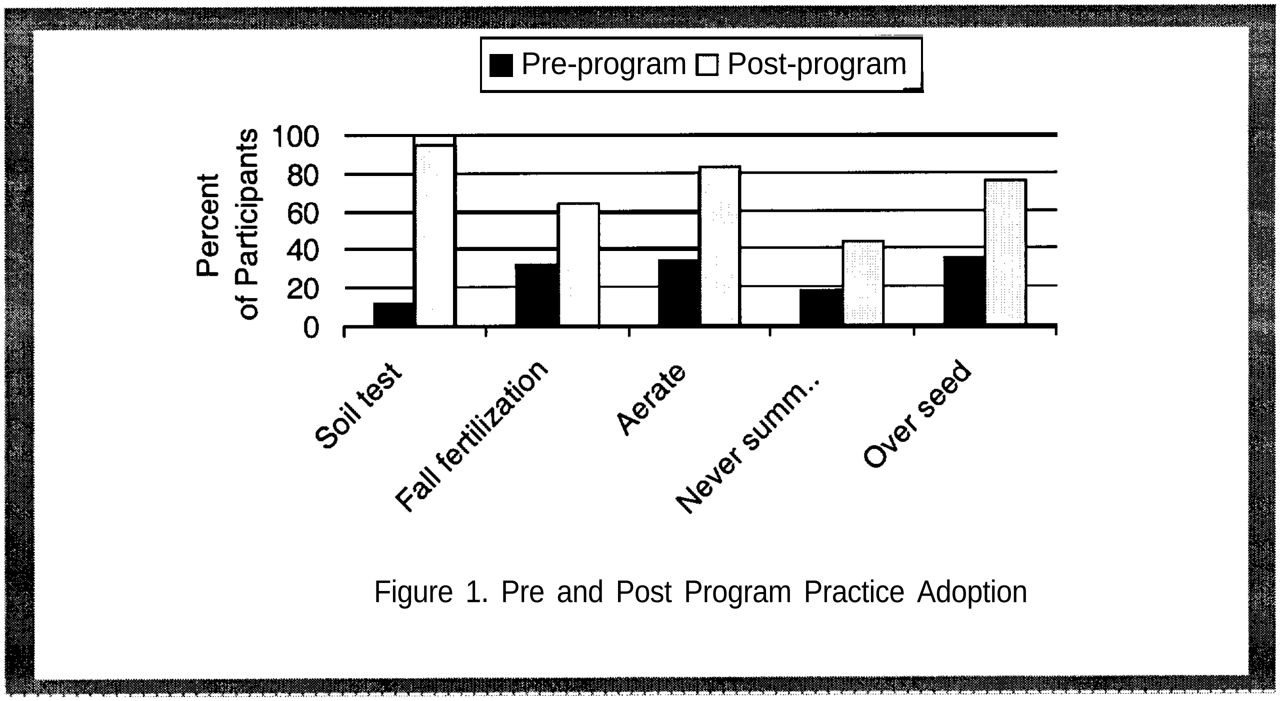

Figure 1. Pre and post program practice adoption.

Conclusions and Lessons Learned

The Water-wise Gardener Program was successful at reaching the intended audience and achieving adoption of nutrient management practices. Based on the success of the program, it appears that suburban homeowners can be recruited to maintain their lawns according to recommended practices. Homeowners are willing, with the help of Master Gardener volunteers in some cases, to keep records on their nutrient use as a part of program participation. Although 326 individuals and 57 acres of turf may seem low for an area like Northern Virginia, it is significant for a populace that does not traditionally participate in water quality educational programs. Considering that most lawns in suburban subdivisions have a turf area of around 5,000 square feet, clearly many individuals will need to be enrolled to reach meaningful numbers.

The study showed that it is difficult to obtain information on pre-program nutrient use for most participants. Most homeowners cannot provide accurate nutrient use data from the previous 6-12 months. They simply do not remember how much nitrogen and phosphorous was in the fertilizer bag applied last spring or fall. However, after program involvement, they do appear to understand how much nitrogen they applied and the square footage of their turf. From a water quality public policy perspective, it may be preferable to record nutrient use after program involvement and consider participants' turf square footage as the urban nutrient management measurement. In this way, the focus could be upon recruiting more and more individuals to participate in nutrient management educational programs like the Water-wise Gardener, thus increasing the number of acres addressed by urban nutrient management efforts. Such an approach could easily be integrated into local Geographic Information Systems, providing localities a simple method of accounting for and reporting on urban nutrient management. Localities interested in a program like the Water-wise Gardener should contact their local Cooperative Extension office to see if a similar project is already occurring or could be developed. As this program is being continued and expanded in the 1999-2001 time frame, the opportunity to better define what is realistic as an urban nutrient management measurement for homeowners will hopefully occur.

Chicago Wilderness; Toward an Urban Conservation Culture

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Chicago Wilderness - Origin and Purpose

We in the Chicago conservation community have been using the word "wilderness" in a highly unconventional context since 1996. We have coined the term "Chicago Wilderness" to refer to the rich biodiversity which resides in and around this huge, sprawling metropolitan area, extending from southeast Wisconsin, through the six-county metropolitan area in Illinois, and around Lake Michigan to northwest Indiana. This is a region which most people think of as anything but "untrammeled by man, where man is a visitor who does not remain," in the words of the Wilderness Act, which has defined our modern concept of wilderness.

This is an area that is associated with--indeed, defined by--humans and their cultural footprint. Although the "wilderness" is scattered throughout the region, mostly in parcels that would be considered slivers of land by conventional wilderness standards, it totals over 200,000 acres of land protected within a complex of national tallgrass prairie, national lakeshore, county forest preserves, city and township parks, and similar preserved public lands. Its protected lands and waters range from half-acre remnants to the 15,000-acre Midewin National Tallgrass Prairie,

Within this system of preserves can be found some of the largest and best woodlands, wetlands, and prairies in the Midwest. These lands are set in a much larger matrix of public and private, developed and undeveloped lands that support nature and the region's 8 million people.

We have called these lands "wilderness," in part to draw the attention of people who are focused on Chicago's cultural attractions to the existence of these lands in their own metropolis, and in part to deliberately blur the distinction, or conversely, emphasize the connections between formal wilderness in remote and inaccessible places and wild lands in the places where people live and work. The biotic connections exist on the land, and they ought to exist in people's minds, as well.

The boundaries of the Chicago Wilderness region do, in fact, capture a spectacular concentration of rare ecosystem types. These ecosystems harbor a high diversity of species, including a large number of those listed as threatened or endangered in the states of Illinois, Indiana, and Wisconsin. Outside of the metropolitan area, particularly in rural Indiana and Illinois, diversity decreases sharply as agriculture dominates the landscape.

"Chicago Wilderness" is also the name we have given the collaboration of over 90 organizations in the Chicago region that have banded together to better protect, restore, celebrate, promote, and publicize our rich biodiversity. An unfortunate and perhaps somewhat inevitable consequence of urban life is a detachment from the land; thus, a principal goal of the partnership is to reconnect a landless urban population, in Aldo Leopold's words, to the "raw material out of which we have hammered that artifact called civilization."

Despite the richness of nature and opportunity for conservation in the region, evidence suggests the Chicago region is experiencing a decline in native species and communities. Prior to protection, much of the region's current base of protected land was subject to agriculture, drainage, and other human influences which reduced or eliminated native plant and animal communities. These areas are often fragmented and isolated from healthy lands which could otherwise serve as immigration sources for native species.

Small fragments are also subject to influences beyond their boundaries, such as urban runoff. Keystone species like wolves and mountain lions, predators which formerly kept prey species like whitetailed deer in check, have been eliminated, and deer now threaten to destroy some of our finest lands through overbrowsing. Many of our protected sites are too small to sustain populations of area-sensitive species, or to retain their full complement of species in the face of random population processes like immigration and emigration. Exotic plant and animal species pose major threats to nearly all of our native communities. Landscape level processes, like fire, that shaped the fundamental character of our ecosystems do not occur with the frequency or to the extent they once did, resulting in shifts in community composition that usually result in a decline in biodiversity.

Chicago area residents are the beneficiaries of farsighted leaders early in the 20th century who established a tradition of setting aside natural land in the urban matrix for the public good, a tradition that our forest preserve districts continue today. The early model was not based on sophisticated concepts of biodiversity conservation, or of ecological processes, but on the museum approach of setting nature aside and not meddling. We now are the beneficiaries of the science of ecology, which begins to tell us how the land mechanism is constructed and how it operates. It is dynamic, not static, and changes occur when landscape processes are interrupted. The science of ecology also reinforces the connections between humans and the rest of nature.

This allows us to reexamine the old model of setting nature aside and leaving it alone. That removes the most immediate threat of development, but it does not address the aforementioned degenerative loss of biodiversity due to fragmentation and alteration of landscape processes. These processes clearly must be reintroduced into our preserves if biodiversity is to be preserved or restored. Prescribed fire must be intelligently applied, invasive species must be controlled, plant and animal species must be reintroduced where they have been eliminated, hydrology must be restored where altered, and science must be improved where our understanding of ecosystem processes is deficient. Perhaps most fundamentally, the people who must support the greatly increased levels of land management and research necessary to restore and maintain our public lands in a healthy condition must have a basic understanding of land health and the value system to commit public resources toward attaining it. Chicago Wilderness, the coalition, is committed to working on all of these fronts.

Quite understandably, the Chicago region's system of public lands was, and perhaps still is, the core of Chicago Wilderness, the initiative. It is what members rallied around during the coalition's formation in 1996. But the vision quickly expanded beyond public lands, for two reasons.

First, our public lands do not exist in isolation. They are part of a much larger land base, and the protected 200,000 acres are affected by what happens on the remaining 6 million acres of the Chicago metropolitan land area. The preserves form the core, but they cannot preserve all the biological parts by themselves since much biodiversity resides on private unprotected land and because they are subject to outside influences.

Biodiversity considerations need to infuse all of the region's land use decisions much more extensively that they do now. Private lands work either in harmony or discordantly with our network of preserves. The link between the two is most apparent in the case of wetland or aquatic habitats, which in many cases are sustained or impacted by runoff from distant areas. Streams, rivers, lakes, and wetlands defy the "protect by fencing" approach. Overall watershed characteristics determine aquatic and wetland habitat quality quite independently of whether the habitat is in a formal preserve or not.

Second, many high-quality, biologically rich pieces of nature persist outside of our preserve system and are threatened by development, along with other stresses like lack of management. Identifying these biologically important areas within proposed developments, redflagging them, designing development with their sustainability in mind, and doing all this with equity for the landowner, is one of our greatest challenges. Nature in the places where we live contributes so much to quality of life, yet maintaining it through the development process resists standard regulatory approaches. There are questions now asked routinely in the subdivision design process: does the plan conform to drainage code, are storm water basins sized properly, is it consistent with surrounding development, does it have proper standards of landscaping? A standard question should be: does it leave the land biologically richer or poorer? We are not yet routinely asking this question, although there are development approaches available that can allow us to answer this question affirmatively.

This question could properly be asked for aesthetic reasons alone, but there are practical reasons for doing so. Native landscapes hold enormous potential for managing storm water and preventing flooding. They hold enormous potential for cleaning up surface waters so that urban waters become fishable and swimmable, instead of the neighborhood joke or eyesore. Finding and applying the template for development that preserves and restores biological diversity, and which serves both aesthetic and utilitarian purposes, is one of the objectives of Chicago Wilderness.

Chicago Wilderness - Structure and Function

Chicago Wilderness formally began as an initiative with the signing of a memorandum of understanding (MOU) by 34 founding members. Members included landowners and land managers; local, state, and federal agencies; centers for research and education; and conservation organizations, among others. These institutions pooled their resources and strengths to form the Chicago Region Biodiversity Council, which has grown to include nearly 100 members.

By signing the MOU, the members of this innovative partnership have pledged a commitment to the protection, restoration, and management of biodiversity in the Chicago region. Four teams focus on central lines of action: science, land management, policy and strategy, and education and communication. The teams attract the participation of many non-member institutions, which adds to the scope and strength of the coalition. Chairs of the teams and other member organization staff form the nucleus of a coordinating group that develops central strategies and maintains momentum. A steering committee of executives oversees the direction of the overall initiatives. Despite this organizational structure, Chicago Wilderness has not become legally incorporated under state law, but remains a loose partnership bound by common goals and objectives.

The potential for Chicago Wilderness to serve as a model for urban conservation attracted the early attention of several federal agencies, including the U.S. Forest Service, U.S. Fish and Wildlife Service, and U.S. Environmental Protection Agency, who have provided significant operating grants. State and private grants have supplemented federal dollars. Direct grants have totaled over 4 million dollars since 1996. This total does not include members' matching funds or funds attracted by members for projects catalyzed, but not directly supported by, Chicago Wilderness.

Chicago Wilderness Accomplishments

The Chicago Region Biodiversity Council funds projects on an annual cycle. The Council's four teams set priorities for these projects; core staff ensure broad participation from team members. Reviewed and approved by a proposals committee, funded projects result from collaboration between member institutions and address critical conservation needs in the region. Since its launch in April 1996, Chicago Wilderness has funded over 130 collaborative projects. In addition to projects funded directly by the Council, the work of our individual member organizations in their own initiatives is central to the success of Chicago Wilderness. Projects completed or underway fall into six categories: characterization and information management; ecological inventory and monitoring; ecological restoration; planning and policy; education, outreach, and public participation; and communications and publications.

Individual projects have included a NASA-supported land cover mapping project; development of models of pre-settlement savannas, woodlands, and forests to guide restoration; assessment of restoration effects on bird communities; a vegetation monitoring workshop; assessment of garlic mustard impacts on native woodland ground flora; development of model restoration interpretive programs; a biodiversity educators workshop; and creation of a Chicago Wilderness Atlas of Biodiversity. An early pilot project supported by Chicago Wilderness was the launching of Chicago Wilderness magazine, a glossy, popular publication on nature in the Chicago area which since has been incorporated as a 501 (c)(3) and has over 7,000 paid subscribers.

Chicago Wilderness Biodiversity Recovery Plan

In 1909, the Commercial Club of Chicago released the "Burnham Plan," a landmark of urban planning that proposed, among other things, a network of public parklands to be set aside for nature and passive recreation. This led to the legislative establishment of a system of such publicly owned preserves for the Chicago region which has continually expanded, and now forms the core of the protected lands that currently comprise Chicago Wilderness.

The Biodiversity Recovery Plan, completed in late 1999, takes the open space component of the Burnham Plan to the next step by creating a vision of sustainability, not only for the core of protected land, but for all of nature and its human inhabitants in the urban area. The recovery plan is a comprehensive statement of what Chicago Wilderness is about, and it is clearly the most ambitious and significant accomplishment of the coalition to date.

This plan is the result of three years of assessment and planning by representatives of the Chicago Region Biodiversity Council. The plan identifies the ecological communities of the greater Chicago region, assesses their condition, identifies major factors affecting them, and provides recommendations for actions needed to restore and protect them into the future in a sustainable condition. In short, the recovery plan outlines the steps necessary to achieve the overall goal of the Chicago Wilderness collaboration, which is to protect the natural communities of the Chicago Region and to restore them to long-term viability, in order to enrich the quality of life of its citizens and to contribute to the preservation of global biodiversity.

To achieve this goal, the recovery plan identifies the following objectives: 1) involve the citizens, organizations, and agencies of the region in efforts to conserve biodiversity; 2) improve the scientific basis of ecological management; 3) protect globally and regionally important natural communities; 4) restore natural communities to ecological health; 5) manage natural communities to sustain native biodiversity; 6) develop citizen awareness and understanding of local biodiversity to ensure support and participation; 7) foster a sustainable relationship between society and nature in the region; and 8) enrich the quality of the lives of the region's citizens.

The plan has many recommendations, some specific and some general, and identifies roles and specific actions for Chicago Wilderness members and the greater public that must be engaged to help implement the plan. The plan's intended intended audiences include the many staff members and general members of Chicago Wilderness institutions, publicagencydecision-makers, large landowners, and all concerned and active citizens who vote and otherwise influence biodiversity conservation in the region.

The recovery plan is both a plan and a process guided by its many sponsors. It is intended as a living document that will continue to evolve as new ideas and information arise. It is intended to complement the many other planning efforts completed or underway in the Chicago metropolitan area that are guiding the region to a better and more productive future. Its ultimate success probably rests on its successful integration into a broader, mainstream regional planning framework that has economic, cultural, social, and environmental components.

Strategic Visioning

After the second year of operation, the Biodiversity Council saw the opportunity to step back and evaluate the structure and function of the coalition during the first two years, consider expectations of members at the outset and evaluate to what extent they were met, and reprioritize its work for the next two years. This process consisted of development of a member questionnaire, convening of a focus group representing a cross-section of members, and a weekend retreat by Chicago Wilderness Steering Committee members and other leaders. It culminated with the development of six priority functions for the next two years, and associated budget requirements.

Some of these functions represent an intensification and refinement of activities the Council is already involved in; in other cases, they represent new endeavors. They include 1) facilitate networking among Chicago Wilderness members, including new orientation materials, workshops, symposia, and lectures; 2) establish an integrated information clearinghouse, including the development of regionwide resource databases, enhancement of the existing web site, and development of more communication resources; 3) increase publicity and outreach to broader audiences; 4) influence key actors outside Chicago Wilderness, including the establishment of a Conservation Policy Committee to develop position statements on regional issues; 5) develop and implement a funding strategy, focusing on large grants from foundations; and 6) implement, promote, and monitor the Recovery Plan.

The Urban Conservation Culture

Conservation efforts in urban areas are often frustrated by the complexity of land use issues, countless players, tangled politics, ecologically wrecked land, and a public dispossessed of nature. Yet it is crucial that we focus on urban areas because of the strong political forces concentrated in urban centers that need to be engaged in national conservation decision-making, and because there is no other way to engage the great majority of people other than to take the messages to them. Moreover, urban residents are still plain members of Leopold's land community, regardless of how obscure the connections, and these connections are best illustrated in the places where they live. Fortunately, the Chicago region has an added bonus of harboring world-class biodiversity, which creates a local, immediately compelling reason for public involvement and action.

Some writers have argued that the American ideal of wilderness has tended to shape our dominant view of nature itself as a place that can only be corrupted by human influence. In urban areas, this has created an assumption that "real" nature cannot exist in these places and it tends to absolve urban residents from local responsibility. Thus, it seems that Chicagoans are much more aware of the plight of Brazilian rain forests that they are of the plight of oak savannas, a globally rare community, in local forest preserves. In remote areas, the standard approach has been to specifically designate areas as wilderness, and then maintain as complete a separation between people and these areas as possible. Chicago Wilderness proposes to redefine wilderness to include local plant and animal communities, which can only be sustained through direct, creative human intervention. A premise of the recovery plan is that if we do not adequately enlist people to directly or indirectly support management and restoration of our lands, they will not become or remain healthy.

It is appropriate to recognize that humans in the Midwest always have influenced landscapes, for better or worse, and that people can be a positive force in maintaining ecosystem health. It may be that by calling a 200-acre patch of prairie in a sea of development wilderness, and by involving people in its stewardship, we can promote a correct sense of unity between the places that we live and remote places we may never see except as pictures on calendars. Restoration and stewardship can be the antidote to dualistic thinking. Remote wilderness and Chicago Wilderness can perhaps then be seen as simply examples of nature, as part of a single system that includes people.

From a relatively straightforward beginning that focused on public land management issues, this, I think, has become the broader goal of Chicago Wilderness--to reconnect people with nature and to make a societal commitment to sustain and nurture nature--for utility, for aesthetics, for spirituality, for all of the equally valid reasons for doing it, on all of our urban lands and in all of our land-use decisions. It begins with a process of educating the public about the natural wealth in the Chicago area, and hopefully ends sometime in the future with the development of an urban conservation culture of concern and personal responsibility for the health of all of our lands, both public and private.

A Survey of Resident Nutrient Behavior in the Chesapeake Bay Watershed

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In recent years a handful of communities have attempted to craft education programs to influence our watershed behaviors. These initial efforts have gone by a confusing assortment of names, such as public outreach, source control, watershed awareness, pollution prevention, citizen involvement, and stewardship, but they all have a common theme -- educating residents on how to live within their watershed.

Many communities will need to develop watershed education programs in the coming years to comply with pending EPA municipal stormwater NPDES regulations. Indeed, half of the six minimum management measures prescribed under these regulations directly deal with watershed education – pollution prevention, public outreach and public involvement. Yet, many communities have no idea what kind of message to send, or what media to use.

In the following presentation, we review the prospects for changing our behaviors to better protect watersheds. We begin by outlining some of the daunting challenges that face educators who seek to influence deeply rooted public attitudes. Next, we profile research on the outreach techniques that appear most effective in influencing watershed behavior. Special emphasis is placed on media campaignsand intensive training programs. Lastly, recommendations are made to enhance the effectiveness of watershed education programs.

Challenges in Watershed Education

Watershed managers face several daunting challenges when they attempt to influence watershed behaviors. Some of those challenges include:

A lot of minds to change

The most pressing challenge is that there are simply a lot of minds to change. Some notion of the selling job at hand can be grasped from Table 1, which contains provisional, but conservative, estimates of potential residential "polluters" in the United States by various categories. It is clear that we are attempting to change deeply rooted attitudes held by millions of people. While most people profess to support the environment, only a fraction actually practice much of a watershed ethic on the small parcels of the environment where they live.

Table 1. Provisional Estimates of Potential Residential Polluters in the United States

Watershed Behavior	Prevalence in Overall Population	Estimates of Potential Residential Polluters
Over-Fertilizers	35%	38 million
Bad Dog Walkers	**15%**	16 million
Chronic Car washers	25%	27 million
Septic Slackers	15%	16 million
Bad Mechanics	**1 to 5%**	3 million
Pesticide Sprayers	40%	43 million
Hosers	15%	16 million

Notes: estimates are based on 1999 U.S. population of 270 million, 2.5 persons per household, and average behavior prevalence rates based on numerous market surveys (See references).

Most Residents are Only Dimly Aware of the Watershed Concept.

It stands to reason that if citizens are asked to practice a watershed ethic, they will need to know what a watershed is. Surveys indicate, however, that the average citizen is unaware of the watershed concept in general, and does not fully understand the hydrologic connection between their yard, the street, the storm sewer, and (finally) local streams. Resident surveys also continue to show limited or incomplete understanding of terms such as "watershed", "stormwater quality" or "runoff pollution". For example, a recent Roper survey found that only41 % of Americans had any idea of what the term watershed meant (NEETF, 1999). The same survey found that just 22% of Americans know that stormwater runoff is the most common source of pollution of streams, rivers, and oceans.

At the same time, most of us claim to be very environmentally aware. For example, a Chesapeake Bay survey reported that 69% of respondents professed to be very active or at least somewhat active in helping to reduce pollution in the environment (SRC, 1994).

Resources Devoted to Watershed Education are Inadequate.

In recent years, several communities have developed education programs to influence the watershed behaviors practiced by their residents. Most of these efforts, however, are run on a shoestring. For example, CWP recently surveyed 50 local programs that have tried to influence lawn care, septic cleaning and pet waste behaviors (Swann, 1999). These education programs are typically run by the cooperative extension services, local recycling or stormwater agencies, or urban soil and water conservation districts. Most are poorly staffed (0.1 to 0.5 staff years), relatively new (within last five years), and have tiny annual budgets ($2,000 to $25,000). Given these limited resources, most watershed education programs have no choice but to practice retail, rather than wholesale, outreach techniques. Consequently, most watershed educators rely heavily on low-cost techniques such as brochures, posters, workshops, and demonstration projects to send their message out.

The Marketing Techniques We Can Afford Don't Reach Many People

Watershed managers need to send a clear and simple educational message that can attract the attention of the average citizen who is simultaneously bombarded by dozens of competing messages every day. A number of surveys have asked residents which outreach techniques are most influential in attracting their attention (Table 2). Messages sent through television, radio and local newspapers are consistently more influential in reaching residents than any other technique, with up to 30% recall rates by the watershed population for each technique. By contrast, messages transmitted through meetings, brochures, local cable and videos tend to be recalled by only a very small segment of the watershed population.

Table 2. Most Influential Methods of Getting Messages to Citizens, in 8 Citizen Surveys

	WA (Elgin, 1996)	OR (AMR,1997)	CA (As-sing, 1994)	CA (Pellegrin, 1998)	MI (PSC, 1994)	WI (Simpson, 1994)	MN (Morris et al., 1996)
TV	TV ad	Direct Mail	TV Ad	TV	TV	TV	Newspaper
TV ad	TV	TV ad	Stencils	Paper	Paper	Paper	Direct Mail
Newspaper	Newspaper	Newspaper	Billboard	Radio	Cable TV	Newsletter	TV
Local paper	Radio Ad	Radio	Local paper	Magazine	Local paper	Brochure	Neighbors
Video	Brochure	TV	Brochure	Neighbors	News-letter	Site Visit	Ext Service
Brochure	Radio news	Bill Insert	Radio Ad	School	Video	Video	Radio
Local cable	Paper Ad	Newsletter	Bus Sign	Billboard	Meetings	Meeting	Meeting
Meeting	Billboard	Local paper	Direct Mail	Brochure	Brochure	--	Local cable

One clear implication is that watershed education efforts must utilize a mix of outreach techniques if they are going to get the message across to enough residents to make a difference in a watershed. Most existing watershed education programs, however, cannot afford to use the more sophisticated *wholesale* outreach techniques that are most effective

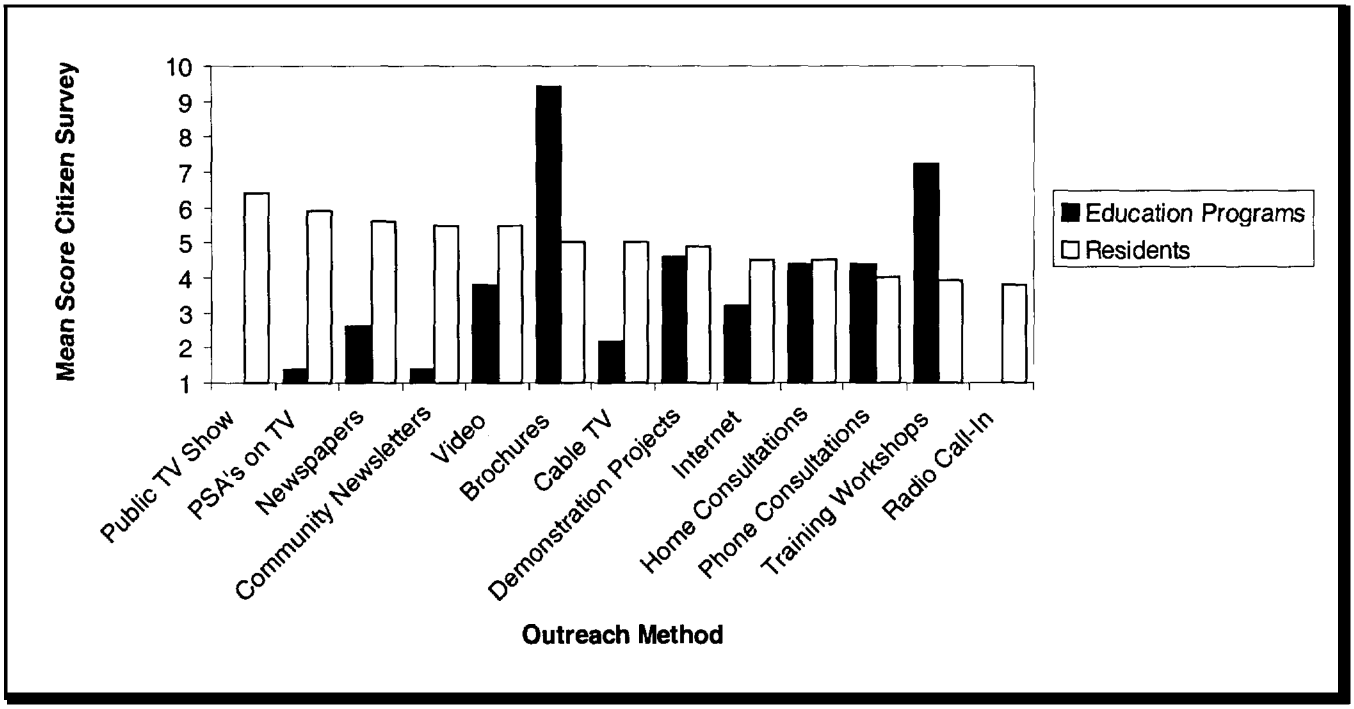

Figure 1. Outreach Methods Preferred By Residents Compared to Those Used by Education Programs.

at reaching the public with their watershed message. This gap is evident in Figure 1, which compares the outreach methods actually used by local watershed education programs with the outreach methods that residents prefer, based on responses from the Chesapeake Bay survey (Swann, 1999).

Crafting Better Watershed Education Programs

The first step in crafting better watershed education programs is to compile some baseline information on local awareness, behaviors and media preferences. Some of the key questions watershed managers should consider are:

Is the typical individual **aware** of water quality issues in the watershed they live in?

. Is the individual or household **behavior** directly linked to **water quality problems ?**

- Is the behavior widely prevalent in the watershed **population ?**
- Do specific **alternative(s)** to the **behavior** exist that might reduce pollution?
- What is the most clear and direct **message** about these alternatives?
- What **outreach** methods are most effective in getting the message out ?
- How much **individual behavior change** can be expected from these outreach techniques?

The best way to elicit this information is to conduct a market survey within the watershed. These market surveys are useful for two purposes: to gauge the level of watershed awareness and interest within the general population, and to determine if there is a segment of the population where education efforts should be focused to achieve the best returns in behavioral changes for the money spent.

Perhaps the most critical step in crafting an education program is to select the right outreach techniques to send the watershed message. Several communities have recently undertaken before and after surveys to measure how well the public responds to their watershed education programs. From this research, two outreach techniques have shown some promise in actually changing behavior -- media campaigns and intensive training. Media *campaigns* typically use a mix of radio, TV, direct mail, and signs to broadcast a general watershed message to a large audience. *Intensive training* use workshops, consultation and guidebooks to send a much more complex message about watershed behavior to a smaller and more interested audience. Intensive training often requires a time commitment of several hours from residents.

Both media campaigns and intensive training can produce up to a 20% improvement in selected watershed behaviors among their respective target populations (Tables 3 and 4). Both outreach techniques are probably needed in most watersheds, as each complements the other. For example, media campaigns cost just a few cents per watershed resident reached, while intensive training can cost a few dollars for each resident that is actually influenced. Media campaigns are generally better at increasing watershed awareness, and sending messages about negative watershed behaviors. Intensive training, on the other hand, is superior at changing individual practices in the home, lawn and garden.

Table 3. Effectiveness of Media Campaigns in Influencing Watershed Behaviors: Four Surveys

Location and Nature of Targeted Campaign	Effectiveness of Campaign
San Francisco Radio, TV and Buses (BHI, 1997)	Awareness increased 1 O-l 5% Homeowners who reduced lawn chemicals shifted from 2 to 5%
Los Angeles Radio and Newspapers (Pellegrin Research Group, 1998)	Best recall: motor oil and litter (over 40%) Worst recall: fertilizer and dog droppings (<10 %) Drop in car washing, oil changing, radiator draining of about 5 to 7% Greater self-reporting of polluting behaviors: dropping cigarette butts, littering, watering and letting water run on street, hosing off driveways into the street (10% or more)
Oregon Radio, TV (Advanced Marketing Research, 1997)	19% reported a change in "behaviors"-changes included being more careful about what goes down drain, increasing recycling and composting, using more nature-friendly products etc.
Oakland County, MI Direct Mail (Public Sector Consultants, 1994)	44% of mail respondents recalled lawn care campaign 50% desired more information on lawn care and water quality 10% change in some lawn care practices as a result of campaign (grass recycling, fertilizer use, hand weeding). No change in other lawn care practices as a result of campaign

Table 4. Effectiveness of Intensive Training in Changing Watershed Behaviors

Location and Nature of Training Campaign	Effectiveness of Intensive Training
Maryland Direct Homeowner (Smith, 1996)	10% shift from self to commercial car washing. No change in fertilizer timing or rates. Better claims of product disposal.
Florida Master Gardener (Knox, 1995)	No significant change in fertilization frequency after program. Some changes in lower rates, labels, slow release (8 to 15%). Major changes in reduced pesticide use (10 to 40%).
Virginia Master Gardener (Aveni, 1998)	30 to 50% increase in soil testing, fertilizer timing and aeration. 10% increase in grass clippings and 10% decrease in fertilizer rate.

Both techniques work best when they present a simple and direct watershed message, are repeated frequently, utilize multiple media and are directly connected to local water resources that are most important in the community.

Other important suggested considerations for effectively marketing a watershed message are to:

Develop stronger connections among the yard, the street, the storm sewer, and the stream. Outreach techniques should continually stress the link between a particular watershed behavior and the undesirable water quality it helps to create (i.e., fish kills, beach closure, algae blooms). Several excellent visual ads that effectively portray this link are profiled in our watershed outreach award winners.

Form regional media campaigns. Since most communities operate on small budgets, they should consider pooling their resources to develop regional media campaigns that can use the outreach techniques that are proven to reach and influence residents. In particular, regional campaigns allow communities to hire the professionals needed to create and deliver a strong message through the media. Also, the campaign approach allows a community to employ a combination of media, such as radio, television, and print, to reach a wider segment of the population. It is important to keep in mind that since no single outreach technique will be recalled by more than 30% of the population at large, several different outreach techniques will be needed in an effective media campaign.

Use television wise/y. Television is the most influential medium for influencing the public, but careful choices need to be made on the form of television that is used. Our surveys found that community cable access channels are much less effective than commercial or public television channels. Program managers should consider using cable network channels targeted forspecificaudiences, and develop thematicshows that capture interest of the home, garden and lawn crowd (i.e., shows along the lines of “This Old Watershed”). Well-produced public service announcements on commercial television are also a sensible investment.

Understand the demographics of your watershed. The middle-aged male should usually be the prime target for watershed education, as he is prone to engage in more potentially polluting watershed behaviors than other sectors of the population. Indeed, the most important audience for the watershed message includes men in the 35 to 55 year age group with higher incomes and education levels. Specialized outreach techniques can appeal to this group, such as radio ads on weekend sports events.

Another target group worth reaching includes what Pellegrin (1998) terms the “rubbish rebels”-- 18 to 25 year olds who tend to have low watershed awareness, engage in potentially polluting behaviors, and are often employed in lawn care and other service industries. This age group is hard to reach using conventional techniques, but may respond to ads on alternative radio, concerts, and other events that celebrate the watershed.

As communities become more diverse, watershed managers should carefully track the unique demographics of their watersheds. For example, if many residents speak English as a second language, outreach materials should be produced in other languages. Similarly, watershed managers should consider more direct channels to send watershed messages to reach particular groups, such as church leaders, African American newspapers, and Spanish-speaking television channels.

Watershed educators should also be careful about using the traditional environmental education model that uses schools to educate children who in turn educate their parents. While this model was instrumental in achieving greater rates of recycling, it may not be as effective in changing watershed behaviors. While it is important to educate the next generation of fertilizers, dog walkers, septic cleaners, and car washers, we need to directly influence the “boomer’ generation now.

Keep the watershedmessagesimpleandfunny. Watershed education should not be preachy complex, or depressing. Indeed, the most effective outreach techniques combine a simple and direct message with a dash of humor.

Make information packets small, slick, and durable. Watershed educators should avoid the ponderous and boring watershed handbook that looks great to a bureaucrat but ends up lining the bottom of a bird cage. One solution is to create small, colorful and durable packets that contain the key essentials about watershed behaviors, with contact information to get better advice. These packets can be stuck on the refrigerator, the kitchen drawer or the workbench for handy reference when the impulse for better watershed behavior strikes.

Educate *private sector allies.* A wide number of private sector companies may potentially stand to benefit from changes in watershed behavior. Better watershed behavior can drum up more sales for some companies, such as septic tank cleaners, commercial car washes, and quick oil change franchises -- although they may need some help in crafting their watershed marketing pitch.

Clearly, the potential exists for lawn care companies and landscaping services to shift their customers toward more watershed-friendly practices. Nationally, lawn care companies are used by up to 50% of consumers, depending on household income and lot size. Lawn care companies can exercise considerable authority over which practices are applied to the lawns they tend, as long as they still produce a sharp looking lawn. For example, 94% of lawn care companies reported that they had authority to change practices, and that about 60% of their customers were "somewhat receptive to new ideas" according to a Florida study (Israel et al, 1995). De Young (1997) also found that suburban Michigan residents expressed a high level of trust in their lawn care company.

Indeed, a small, but growing proportion of lawn care companies feel that environmental advertising makes good business sense and can increase sales (Israel et al, 1995). Clearly, intensive training and certification will be needed to ensure that watershed-friendly ads reflect good practice and not just slick salesmanship. It needs to be acknowledged that lawn care companies strongly committed to practices that reduce fertilizer and pesticide inputs need to be strongly endorsed by local government. Right now, it is not likely that such companies would be selected by the average consumer, as consumers primarily rely on direct mail, word of mouth, and cost when choosing a lawn care company (Swann, 1999 and AMR, 1997). For example, in the Chesapeake Bay survey, only two percent of residents indicated that they had chosen a lawn care company primarily on the basis that it was "environmentally friendly" (Swann, 1999).

Lawn and garden centers are another natural target for watershed education. Study after study indicates that product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer. At first glance, national retail chains should be strongly opposed to better watershed behavior, since it would sharply cut into lawn and garden product sales and the lucrative profits they produce (even at the expense of the community and environmentally friendly image they often market). The key strategy is to substitute watershed-friendly products for ones that are not, and to offer training for the store attendants at the point of sale on how to use such products.

Summary

For the watershed manager faced with new regulatory requirements under Phase II of the NPDES program, the creation of an effective watershed education program should be a high priority. Not only is public education a mandated component of an NPDES permit, but in urbanized areas it may the most cost-effective tool available to achieve water quality goals. For smaller communities with scant budget and staff resources, it is imperative that these education programs be productive in terms of changing behaviors and raising awareness of individual actions on local water quality.

Perhaps the most important factor in creating an effective watershed education program is selecting the right outreach methods. Market surveys will often answer questions regarding the level of environmental awareness of watershed residents, what forms of informational outreach attract their attention, and resident willingness to change pollutant producing behaviors. This information allows the watershed manager to tailor outreach methods to specific target groups where behavior change is most likely. These surveys will also establish the demographics of the residents and determine whether multilingual outreach is required.

Watershed managers should also consider innovative approaches to sending out their pollution reduction messages. Pooling resources with other communities to create regional media campaigns and the use of outreach opportunities through private sector education are just two ways that program managers can reach broader audiences without spending large amounts of money.

Continued development of productive outreach methods and innovative techniques is necessary to relay the basic premise of watershed education - that we live in a watershed and how to properly live within it - in the most economical and effective manner.

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Lawn Care and Water Quality: Finding the Balance

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Abstract

When land is converted from natural areas to developed urban areas, pavement and rooftops replace grass and trees. Water flows over driveways, streets and parking lots taking with it particles and debris in its path and depositing them, via storm sewers, into nearby lakes, creeks and rivers. This non-point source pollution can contain sediment, debris, fertilizers, pesticides, leaves, grass clippings, motor oil, or pet wastes. Small amounts of these materials entering a lake or river are not generally considered harmful. But when small amounts are multiplied by thousands or tens of thousands they can cause serious water quality problems.

Since 1993, the Minnesota Department of Agriculture, in cooperation with several other organizations, has been gathering information on homeowner use of pesticides and fertilizers in the Twin Cities metropolitan area. This information includes the amounts of lawn care products used by homeowners, where they are purchased, how they are applied, and whether or not they have an effect on nearby lakes, creeks or rivers.

Residents living in two watersheds were selected to participate in a focused study. Lake Harriet represents urban watersheds and Lake Alimagnet represents suburban watersheds. Based on survey results and water quality monitoring, education materials were developed to promote public awareness of lawn practices and their potential to affect water quality. These educational materials incorporate the concept that "everyone lives in a watershed" and that everyone has the potential to affect water quality, whether or not they actually live on a lake shore.

What are the Lake Harriet and Lake Alimagnet Watershed Awareness Projects?

The projects have two purposes: (1) to inform urban and suburban homeowners about living in a watershed, and (2) to help them learn how their lawn care habits can affect the quality of Twin Cities water. The project's goal is to improve water quality by reducing the quantity of pesticides and nutrients through responsible use of those materials.

How has this goal been achieved?

Project members have:

- Surveyed the current lawn care habits of homeowners and measured the effects of those habits by monitoring pesticide and nutrient runoff into Lake Harriet
- Informed homeowners about how their lawn care habits affect Twin Cities waters
- Asked homeowners how the projects have affected their lawn care practices
- Monitored runoff into Lake Harriet to quantify changes brought about by homeowner actions
- Drawn on detailed Lake Harriet experience to design urban watershed education materials for use throughout Minneapolis and Minnesota--these materials were tested in the Lake Alimagnet watershed

What is a watershed?

It is an area of land over which rain and melted snow flows to lakes, rivers, and wetlands. There are 46 major watersheds and 255 sub-watersheds in the Minneapolis-St. Paul metropolitan area.

The Lake Harriet watershed is a 1,139-acre area in a well-established residential neighborhood with almost 6,000 homeowners. The Lake Harriet study area is a 148-acre portion of the watershed. About 40% of the study area is covered with hard surfaces, such as pavement and rooftops. About 700 homeowners live in the study area, most in detached, single family houses built in the early 1900s. The water quality in Lake Harriet is very good for a Twin Cities lake.

A survey of 105 Lake Harriet watershed residents most familiar with lawn care done on their own properties, showed that:

- They are highly educated (college or post-graduate degrees predominate)
- Their average age is 47
- They have middle- to upper-level incomes
- They care for their lawns by mowing regularly and using fertilizers and herbicides
- A few use professional lawn care services

The Lake Alimagnet watershed has approximately 3600 suburban households. Of this number, a large proportion is made up of townhouse residents. The Lake Alimagnet watershed was developed in the 1960s. Homeowners are well-educated and have middle- to upper-middle incomes. The water quality in Lake Alimagnet is considered poor, algae blooms are common, and the predominant fish species is bullhead.

Why are we studying the Lake Harriet and Lake Alimagnet watersheds?

Because they provide good examples (respectively) of how urban and suburban development affect our water resources and because they are sources of year-round recreation for many Twin Cities residents. These residents are vitally interested in keeping the water clean.

What are we finding out?

Though Lake Harriet had some of the highest quality water in the Twin Cities, that quality has also declined over time. Lake Harriet has poor quality water and area residents want to reverse the trends.

These projects and others have monitored storm water, rainfall, and lake water to determine the levels of non-point source pollutants in Lake Harriet. Specifically, this project monitored two types of pollutants: pesticides, which can affect water quality, and phosphorus, which can increase lake algae growth and reduce water quality.

Pesticide monitoring

The Lake Harriet project monitored storm runoff, rainfall, and lake water. The water quality monitoring consisted of a permanent automatic sampling station installed in a storm drain outlet which carried watershed runoff into Lake Harriet; samples were taken during storm events, from which mass loading of pesticides and nutrients were calculated. In addition, a rainfall monitoring station sampled rain events. Finally lake monitoring samples were collected during the growing season. Several hundred samples were analyzed for more than 30 pesticides.

The education program included several methods of education, including homeowner meetings, direct mail, flyers, billboards, utility bill inserts, local newspaper articles and visits by Master Gardeners. Because monitoring preceded the education, and also followed it,reductions in pesticides can be measured. There was a decrease in average pesticide loads between the earlier and later monitoring periods. Therefore, the annual storm sewer runoff load of pesticides to Lake Harriet was reduced during the Lake Harriet project. The largest decreases came from the four compounds listed on this table:

Lawn Herbicides	**Percent Decrease** (1992-l 995)
MCPA	86%
Dicamba	59%
2,4-D	58%
MCPP	56%

The most prevalent pesticides found during monitoring were herbicides (weedkillers). The eight herbicides listed on the following table accounted for 95% of all pesticide detections.

Lawn Herbicides	**Agricultural Herbicides**
MCPA	Alachlor
Dicamba	Atrazine
2,4-D	Cyanazine
MCPP	Metolachlor

- **Storm water runoff monitoring summary:**
  - Lawn herbicides were found in 80% of the storm runoff events sampled between April and October.
  - Agricultural herbicides were detected in 35% of the storm events sampled
- **Rainfall monitoring summary:**
  - The agricultural herbicides listed above (the only herbicides found in rainfall samples) were atmospherically deposited by wind and rainfall onto the watershed and the accompanying water bodies.
  - Lawn herbicides were not detected in rainfall samples.
- **Lake monitoring summary:**
  - The three most commonly detected compounds in lake water were MCPP, Atrazine, and 2,4-D. They were also the most frequently detected compounds in stormwater entering Lake Harriet.
- **Phosphorus monitoring:**

Analyses revealed the phosphorus in runoff peaks twice a year, in the spring and in the fall.

- In the spring, melting snow carries phosphorus attached to tiny particles of grit, sand, and organic matter as it enters the storm sewers.

- In the fall, phosphorus in leaves, grass clippings, and other organic debris enters the storm sewers. Studies conducted by other researchers established that only a small percentage of phosphorus in runoff results from appropriate use of fertilizer on lawns.

- **Water Quality Education**

Lake Harriet and Lake Alimagnet project participants have concluded that educating homeowners living in the watershed is one of the best ways of reducing pollution in the lake. Billboards, brochures, and water bill inserts have carried messages based on the following two concepts:

- **A healthy lawn and landscape promotes healthy waters.** Home landscaping with regionally adapted, healthy plants can help absorb and filter rainfall, irrigation, and runoff from melted snow.

- **Keep your lawn and landscape healthy as follows:**
  - Apply pesticides and nutrients according to recommendations
  - Aim roof downspouts onto lawns and gardens to filter and absorb runoff
  - Keep grass clippings and leaves off streets, sidewalks, and driveways
  - Leave grass clippings on the lawn or compost them
  - Use fallen leaves as winter or summer mulch, compost them, or shred them and leave them on the lawn
  - Keep lawn care products on the lawn and always follow label instructions
  - Clean up and reuse granular lawn care products that fall on streets, sidewalks, and driveways

Project Evaluation

- Based on feedback from homeowners living in the Lake Harriet and Lake Alimagnet watersheds, we have concluded the following:
  - Most homeowners in the Lake Harriet watershed apply significantly less lawn fertilizer than the University of Minnesota's recommended guidelines.
  - Most homeowners compost grass clippings or leave them on their lawns.
  - Homeowners would rather spot-treat weeds than apply herbicide to their entire yard or use non-chemical weed control methods.
  - Top soil in the Lake Harriet watershed is significantly deeper than that found in the Lake Alimagnet watershed. In many cases when suburban areas are developed, top soil is removed, but not replaced. This results in decreased plant vigor, and an increase in the need to fertilize, water, and maintain turf.
  - Most homeowners feel the educational initiative has increased their understanding of how lawn care habits affect water quality. Neighborhood newspapers and direct mail, the most common source of lawn care and water quality information, have the greatest impact.
  - Messages that are quick to read and easy to understand are the most effective in changing lawn care habits.
  - These messages are best delivered over an extended period. Homeowners have been reached through fliers, newspaper articles, brochures, direct mail, handouts, and personal contacts.

Feedback also shows that homeowners still need to hear the following messages:

- You can preserve water quality and have a healthy lawn by applying lawn care products in appropriate amounts, at the right times, and during suitable (or appropriate) weather conditions.
- By keeping leaves out of storm sewers, you can help reduce the amount of phosphorus carried to the lake in runoff water.
- Fall is the best season to apply turf fertilizers and lawn care products that control broadleaf weeds. The primary growth of turf grasses is early fall until late spring.
- Erosion, leaves, grass clippings, yard waste, pet waste, and rainfall all contain pollutants that can end up in lake water.

Lake Alimagnet Project Results

During the project period, the water quality in Lake Alimagnet improved significantly.

- Project cooperators achieved improvements in total phosphorus and chlorophyll-a.
- The best secci disk reading ever on Lake Alimagnet **was** recorded.
- The Citizens Assisted Monitoring Program improved the ranking of Lake Alimagnet from a **"D"** to a "C."

These results may be a result of the project, a curly leaf pond weed cutting, or may be credited to El Nino.

For more information on the Lake Harriet or Lake Alimagnet Watershed Awareness Projects and samples of homeowner education materials, please contact the Minnesota Department of Agriculture at (651) 297-7269.

San Francisco Bay Area's Pesticide Toxicity Reduction Strategy

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Introduction

Water quality research conducted by San Francisco Bay Area stormwater programs and wastewatertreatment plants over the last several years has identified widespread toxicity in local creeks and wastewater treatment plant effluent (California Regional Water Quality Control Board, 1997; San Francisco Bay Area Pollution Prevention Group, 1998). The toxicity problem was ultimately traced to diazinon and chlorpyrifos-commonly used organophosphate pesticides available in hundreds of consumer products (Alameda Countywide Clean Water Program, 1997). Study results indicated that pesticide use according to label instructions could not be ruled out as a cause of wastewater and stormwater toxicity (Regional Water Quality Control Plant-Palo Alto, 1996). In May 1999, San Francisco Bay and 35 Bay Area urban creeks were listed by the U.S. Environmental Protection Agency (USEPA) as impaired by diazinon (USEPA, 1999).

Impact of 303(d) Listing on Local Governments

In its action, USEPA listed 53 waterbodies in California as impaired due to diazinon in urban runoff and 7 waterbodies as impaired due to chlorpyrifos in urban runoff. By definition under the Clean Water Act, this action means that there is a water quality problem, regardless of the problem definitions under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (i.e., "unreasonable adverse effect") or the Food Quality Protection Act (FQPA). The listing action put over 100 municipalities in the San Francisco Bay Area and Central Valley at immediate regulatory, legal, and financial risk.

- Regulatory risk -The State Water Resources Control Board and USEPA can take enforcement action against, and fine, these municipalities for violating their NPDES (National Pollutant Discharge Elimination System) stormwater permits.

- Legal risk - Citizen and environmental groups can sue municipalities for the same reasons.

- Financial risk - These municipalities must now spend local public tax dollars proactively addressing this problem, and potentially reacting to fines and lawsuits.

Municipalities' Response

To comply with their NPDES stormwater permits, municipalities must meet two broad goals:

1. Effectively prohibit non-stormwater discharges into storm sewers.

2. Reduce the discharge of pollutants to the maximum extent practicable (MEP).

To meet these goals and to address the 303(d) listing, there are a number of actions Bay Area stormwater programs have taken or plan to take that may reduce pesticide-related toxicity in surface waters. These actions are packaged in a Pesticide Toxicity Reduction Strategy (BASMAA, 2000). The Strategy is a multi-faceted effort including:

- Education/outreach including:

- limiting or prohibiting pesticide use by municipal staff and contractors and/or requiring use of best management practices (BMPs) such as Integrated Pest Management (IPM)
- providing adequate and convenient options for disposal of unused pesticides and pesticide containers through household hazardous waste collection programs
- educating residents about pesticide-related toxicity and proper use and disposal through distribution of educational materials, and development and implementation of media and advertising campaigns
- educating residents about alternative methods and products through such programs as demonstration gardens and point-of-purchase campaigns in hardware stores and nurseries
- educating businesses about proper use and disposal, as well as alternative methods and products for use around their own properties and facilities
- educating pest control operators and working with them to develop BMPs protective of surface waters
- Regulatory- Identifying opportunities to reduce toxicity and advocating state and federal agencies to seize these opportunities through regulation and re-registration
- Monitoring - Investigating the extent and causes of toxicity, and assessing impacts on beneficial uses

The IPM Store Partnership

One exemplary part of the Pesticide Toxicity Reduction Strategy worth describing in more detail is the IPM (Integrated Pest Management) Store Partnership. In 1997, the Central Contra Costa Sanitary District (CCCSD), a wastewater treatment plant located in Martinez, California, jointly developed and successfully piloted the IPM Store Partnership with the Regional Water Quality Control Plant (Palo Alto, California) in four locally owned garden centers and hardware stores. In 1998, the Bay Area Stormwater Management Agencies Association (BASMAA) and the San Francisco Bay Area Pollution Prevention Group (BAPPG) joined together to fund the expansion of the IPM Store Partnership to more stores in the San Francisco Bay Area. By spring 1999, 116 stores in eight Bay Area counties were participating in the Partnership.

The Partners

BASMAA is a consortium of seven San Francisco Bay Area municipal stormwater programs. These programs represent more than 90 agencies, including 79 cities and 6 counties, and the bulk of the watershed immediately surrounding San Francisco Bay. BASMAA agencies agree to a memorandum of understanding and each year collect dues, prorated by population, from their members for a “baseline” program that provides for staff and finances projects-like the IPM Store Partnership–that are endorsed by all member agencies.

The BAPPG is a voluntary association of 39 wastewater treatment plants working together to prevent water pollution in the San Francisco Bay. These agencies represent all of the publicly owned municipal wastewater agencies that discharge into San Francisco Bay in the nine Bay Area counties, and almost all of the watershed immediately surrounding San Francisco Bay. BAPPG’s decision-making is done by consensus. Each year, a work plan-with an associated budget-is developed. The budget is allocated among the 39 plants based on the average amount of treated wastewater discharged each day. Contributions are voluntary, although all agencies do contribute. These contributions are used to fund projects like the IPM Store Partnership.

Integrated Pest Management

There are many definitions of Integrated Pest Management. The definition used to guide the IPM Store Partnership was the following:

Integrated Pest Management is an approach that uses regular monitoring and cultural, biological, and physical methods to keep pests at acceptable levels. Only less toxic chemicals are used and only as needed.

IPM was used as the basis for the program because it: (1) focuses on effective alternatives to traditional chemical pesticides; (2) does not substitute another pesticide that may become tomorrow's problem, and (3) does not preclude the use of chemicals in all situations.

Although promotion of IPM was the basis for the program, the term itself is somewhat problematic. The terms "IPM" and "Integrated Pest Management" were used in speaking with experts and agencies familiar with the jargon, but these terms were avoided in communications with the non-initiated (e.g., general public). In addition, the term IPM was not very representative of the situation in the store between the customer and the store employee. Most customers go to a store for help when pests have already reached unacceptable levels, so store employees must start with controlling a pest problem, rather than preventing it, which is the first step in IPM. Despite this challenge, customers were exposed to the full range of IPM methods through the fact sheets and display materials, as well as less-toxic products.

Goals

The goals of the IPM Store Partnership are to:

- Educate the public about the value of IPM approaches to pest control and safe use and disposal of pesticides, when used
- Deliver IPM-related messages without negative messages about any products
- Develop partnerships with retailers so that they can help spread the word about water quality problems related to residential pesticide use
- Provide consistent messages
- Capitalize on economies of scale
- Prepare the stage for regional program expansion into chain stores

Program Elemen ts

The IPM Store Partnership is an education program for employees and customers of locally owned garden centers and hardware stores. The project elements include:

- development and production of eight fact sheets on less-toxic pest management strategies for the public *(Naturally Managing Pests, Controlling Ants, Controlling Aphids in Your Garden, Keeping Cockroaches Out of Your House, Keeping Fleas Off Your Pets and Out of Your Yard, Living with Spiders, Tips for a Healthy Beautiful Lawn, and Safe Use and Disposal of Pesticides)*
- development of an extensive list of less-toxic methods and products preferable to diazinon and chlorpyrifos for various applications
- training sessions for store employees focusing on principles of Integrated Pest Management and successful application strategies for products on the less-toxic list
- design and production of a program logo and in-store promotion materials including "end cap" displays, posters, shelf-talkers, shelf signs, and vinyl banners
- program evaluation by a San Francisco State University-affiliated survey research and data analysis firm

Results and Discussion

Although the final evaluation will not be complete until the end of the 1999 in-store promotion season (late 1999), the sponsoring agencies expect it to be successful based on preliminary findings and on the success of the pilot project. Feedback from store owners and employees that participated in the pilot was uniformly positive. The sales data in the pilot IPM Store Partnership showed variations from store to store. One store found that sales of all but one diazinon and chlorpyrifos product dropped. At the same time, less-toxic product sales experienced an overall 17% increase and profits were not affected.

It is the hope of the participating agencies that the final evaluation and report on the 1999 Partnership will be useful as a model and primer for other agencies and jurisdictions concerned about pesticide-related toxicity in surface waters and interested in building educational partnerships with local businesses. While Bay Area water pollution prevention agencies have been coordinating their public education efforts since the early 1990s, the IPM Store Partnership is the first point-of-purchase program implemented regionally. All of the general benefits of inter-agency coordination (support for smaller agencies, cost savings, options for pooled advertising and media relations) are magnified in such a large undertaking.

Based on the partnership's success, all of the agencies that participated in the 1999 Partnership allocated funds for continuation of the program in 1999-2000. BASMAA and the BAPPG again contributed funds to regional coordination. Brainstorming sessions were held in late summer 1999 to determine how to improve the program, and minor modifications were made for 2000.

The IPM Store Partnership is one example of BASMAA and the BAPPG's commitment to use public resources efficiently. Given that philosophy, materials developed by the IPM Store Partnership are available to agencies interested in implementing a similar program.

Other Aspects of the Strategy

Despite the success of the IPM Store Partnership and many of the other educational aspects of the Pesticide Toxicity Reduction Strategy, it is clear to Bay Area water pollution prevention agencies that their efforts alone will not be enough to solve the problem. Study results indicate that less than 1% of applied diazinon runs off, yet it takes less than a fluid ounce of active ingredient flushed into stormwater runoff to cause toxicity in urban creeks (Regional Water Quality Control Plant-Palo Alto, 1996). Educational programs run by Bay Area water pollution prevention agencies are some of the most developed in the country and they have won numerous awards for their quality and effectiveness. Nevertheless, even the best education programs are not 100% effective. It is clear that education alone will not solve this problem.

San Francisco Bay Area stormwater programs are and will continue to address the problem of pesticide-related toxicity in surface waters by way of meeting the MEP requirement in their NPDES permits. These agencies have gone so far as to develop the Pesticide Toxicity Reduction Strategy described above that includes three elements-education, regulatory, and monitoring. The authority and ability of local governments to implement the strategy varies with each element. The most cost-effective and appropriate aspect for local governments to implement is education. For the regulatory and monitoring elements, local governments can, and have, identified the issues and opportunities to reduce pesticide-related toxicity, but they have limited ability or authority to actually implement corrective actions.

Regulatory

Regulation of pesticides including their registration for use in the Unites States is the responsibility of USEPA. California's Department of Pesticide Regulation (DPR) has responsibility for regulating the sale and use of pesticides in California. California DPR, with few exceptions, registers pesticides only after they have been registered by USEPA. California DPR can not register pesticides which have been denied registration by USEPA. At the local government level, the California Food and Agriculture Code grants some authority to county agricultural commissioners for local enforcement of pesticide regulations, record keeping, and outreach to applicators. However, with the exception of county agricultural commissioners, local governmentsare prohibited from regulating the registration, sale, transportation, or use of "economic poisons." This regulatory structure means that the ability and authority of local governments is limited to:

- identifying opportunities to reduce toxicity, such as eliminating potentially problematic uses, and advocating that state and federal agencies seize these opportunities through regulation and re-registration

- in the case of wastewater and stormwater agencies, regulating the discharge of pesticides to the sewer or storm drain to ensure local agencies' compliance with state and federal laws (e.g., Clean Water Act)

Monitoring

Local governments have some ability, authority, and responsibility to use monitoring to address the problem of pesticide-related toxicity of surface waters. To-date, San Francisco Bay Area municipalities have used monitoring to:

- identify and define the problem (Alameda County Urban Runoff Clean Water Program, 1995; Regional Water Quality Control Plant-Palo Alto, 1996; California Regional Water Quality Control Board, 1997; San Francisco Bay Area Pollution Prevention Group, 1998)

- characterize sources (Alameda Countywide Clean Water Program, 1997)

- recommend corrective actions (Alameda County Flood Control and Water Conservation District, 1997)

A review of monitoring data from around the country shows that municipalities in the San Francisco Bay Area and California Central Valley are not alone in their identification of this environmental problem.

- Orange County, California (Lee, et al., 1999) – Multi-year studies of stormwater runoff in San Diego Creek as it enters Upper Newport Bay have shown that the problem is not restricted to Northern California. Runoff from each stormwater event has been shown to be toxic, and about half of the observed toxicity is due to diazinon and chlorpyrifos used in urban areas for structural termite and ant control, and lawn and garden pest control.

- NAWQA (USGS, 1998) – Results from the United States Geological Survey's (USGS) National Water Quality Assessment Program from 1992 through 1996 show that the problem is in fact a national one. Over 300 samples have been taken from eleven urban streams scattered across the country, from Florida to Connecticut to Oregon, as part of the Pesticides National Synthesis Project. In a recent report on the first cycle of the program, USGS concluded that "urban and suburban areas are substantial sources of pesticides to streams" and that "most urban areas have similar pesticides in streams...and many urban areas may benefit from similar strategies for reduction."

- Publicly-Owned Treatment Works survey (USEPA, 1989) – Results from a survey done 10 years ago by USEPA show that pesticide-related toxicity is a wastewater problem as well as a stormwater problem. USEPA's Environmental Research Laboratory in Duluth, working through the National Effluent Toxicity Assessment Center (NETAC), reported on the occurrence of diazinon in 28 POTW effluents. Diazinon was found in sixteen (62%) of the effluents, and levels were greater than or equal to 250 ng/L for nine (32%) of the effluents. NETAC concluded in part "The frequency with which we have observed diazinon in the past, in this survey, and continue to find it in effluents is indicative of a widespread problem."

Clearly this is a national problem caused by products that are registered at the national level and sold across the country.

The pesticide registration process provides a built-in mechanism to use monitoring and science to address this national problem. During the registration process, USEPA must review and summarize the findings of studies conducted on each pesticide. During this step, USEPA may request that "registrants" (e.g., pesticide manufacturers) submit specific studies for review. Based on its review, USEPA can confirm, deny, or change the pesticide's registration including approved uses, sites of application, formulations, and label directions.

Local governments are willing to use monitoring and science to further investigate local impacts and sources, and to host case studies, if USEPA will provide financial and other support, with the goal of conducting representative case studies whose results can be extrapolated across the country. But given the established mechanism in the pesticide registration process, it would be inappropriate and ineffective for local governments to do more. USEPA must exercise its federal authorities and use monitoring and science information to make more informed, up-to-date registration decisions.

Conclusion

Rather than being a tool in and of itself, the Pesticide Toxicity Reduction Strategy is really a toolbox. It includes a number of effective tools for reducing pesticide-related toxicity of surface waters-an increasingly important part of urban water resource management and protection. Every job has its tool and in the right pair of hands, the job can be easy and cost-effective to complete. The wrong tool or the wrong hands can make the job difficult, if not impossible to finish. It is the responsibility of government agencies to be clear and disciplined about which tool and which pair of hands go with which job when fixing environmental problems. The extent to which they implement that concept will determine how successful the work of environmental protection will be.

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Administering the NPDES Industrial Storm Water Program at the Municipal Level

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Abstract

As part of the EPA Phase 1 stormwater requirements, certain classes of industries are required to obtain Industrial Storm Water permits. The EPA, or a state agency that has been delegated by EPA, administers these permits. The Phase 1 regulations also require that municipalities develop a program to monitor and control pollutants in storm water runoff from industrial facilities. These are potentially non-coordinated requirements and can result in redundant efforts and a less than efficient program. In addition, EPA and/or state agencies may not have the resources to adequately administrate and enforce the permitting program while leaving the municipality liable for the discharges from the municipal separated storm sewer system (MS4).

The City of Portland, Oregon (City), met the requirement in its municipal storm water permit to control industrial stormwater sources of pollution by developing a Memorandum of Agreement (MOA) with the Oregon Department of Environmental Quality (DEQ), (which is the delegated authority) to administer the permit program. The MOA provided the City with the mechanism to administer the industrial stormwater permits for those facilities that discharge to the City's MS4. The City pursued this approach since it was responsible for the discharge from the MS4 and wanted to ensure that it had adequate oversight of these discharges. By coordinating this effort with other ongoing industrial water quality programs, the City could provide a more cost-effective program, considering the regulatory costs as well as cost to the industry. City Code was developed to support this approach.

When the City took over the administration of the permits in 1994, over 50% of the facilities with a permit had not met the requirements for the development of a storm water pollution control plan, the main requirement of the permit. In addition, nearly 60% of the permitted facilities had not performed the required stormwater sampling. Of the samples taken, approximately 30% violated standards in the permit. It was also evident that not all facilities required to obtain a permit had done so. Efforts since 1994, have shown that only 25–30% of the facilities required to obtain a permit had applied. A benefit of the local administration of the program is the detection of illicit discharges to the MS4. Approximately 15% of all industrial inspections have identified illicit discharges.

The City has also identified certain classes of industries and activities that can be significant sources of pollutants to the MS4. This has helped streamline the program efforts and redirect resources to where the greatest cost benefit will be realized.

Introduction

Stormwater discharges have been increasingly identified as a significant source of water pollution in numerous nationwide studies on water quality. To address this problem, the Clean Water Act Amendments of 1987 required EPA to publish regulations to control storm water discharges under NPDES. EPA published storm water regulations (55 FR 47990) on November 16, 1990 which require certain dischargers of storm water to waters of the United States to apply for NPDES permits. These regulations established NPDES permit application requirements for storm water discharges associated with large- and medium-size MS4s. The regulations also established NPDES permit application requirements for storm water discharges associated with industrial activity. EPA has defined this phrase in terms of 11 categories of industrial activity.

A requirement of the City's application process was "A description of a program to monitor and control pollutants in storm water discharges to municipal systems from municipal landfills, hazardous waste treatment, disposal, and recovery facilities, industrial facilities that are subject to Section 313 of Title III of the Super-fund Amendments and Reauthorization Act of 1986 (SARA), and industrial facilities that the municipal permit applicant determines are contributing a substantial pollutant loading to the municipal storm sewer system." (40 CFR 122.26(d)(2)(iv)(C). This creates the potential for redundant efforts and a less than efficient program.

The stormwater regulations envision that NPDES permitting authorities and municipal operators will cooperate to develop programs to monitor and control pollutants in storm water discharges to MS4 from certain industrial facilities. The NPDES permits for industrial facilities establish requirements such as controls, practices, and monitoring of stormwater discharges, as well as provide a basis for enforcement actions. An integral part of the requirement is the adequacy of legal authority. This will allow the municipality to implement its program, which should include inspections, review of stormwater pollution control plans, monitoring, and implementation of control measures.

The municipality is ultimately responsible for discharges from its MS4. To meet the requirement in its municipal stormwater permit, and to provide the oversight necessary to protect itself from liability, the City developed new legal authority and entered into an MOA with the authorized NPDES state authority (DEQ), to administer the permits for those discharges to the MS4.

Program Elements

Legal Authority

The City did not have adequate legal authority to oversee discharges to the MS4. In response to this, the City developed code in February 1994. Some of the major provisions of the code are:

- Authority of the Director of Environmental Services to Adopt Rules
- General Discharge Prohibitions
- Discharge Limitations
- Reporting Requirements
- Storm Water Pollution Control Plan (SWPCP)
- Storm Water Discharge Permits
- Inspection and Sampling
- Enforcement

Key elements of the code include the requirement for permit holders to submit their SWPCP and monitoring results to the City, the authority for the Director to adopt administrative rules, make inspections, and undertake enforcements.

Memorandum of Agreement

The City entered into a MOA with the DEQ in March 1994. The MOA delineates the responsibilities for the implementation of the program between the two agencies. The MOA also prioritizes the implementation of the program to address those facilities that are of most concern first. Key elements of the City's responsibilities include:

- Development of an inspection and monitoring program
- Informing DEQ of any new or existing facilities that require a permit
- Enforcement of City Code

Key elements of DEQ's responsibilities include:

- Issuance of NPDES Industrial Storm Water permits upon referral or approval by the City
- Denial of permit applications for process wastewater discharge into the MS4
- Enforcement where the City lacks authority

Inspections and Monitoring

The section responsible for the implementation of the program is an autonomous work group. It is housed in the Source Control Division, which includes the pretreatment program. In November 1994, two inspectors were hired to implement the program under an existing supervisor. DEQ, which had been issuing permits since September 1992, provided a list of facilities with stormwater permits. A letter was sent to the permit holders requesting that they submit their SWPCP and all monitoring results. The letter referenced the MOA and included code citing the City's authority. Inspections were prioritized based on problematic outfalls as determined from information gathered in the Part 1 and 2 application process.

Inspections are usually scheduled in advance with the facility operator but can be performed without notice. Inspection forms are filled out during the inspection and any readily noticeable issues addressed during a post inspection meeting. Technical assistance is provided and information on Best Management Practices given in the form of verbal suggestions and reprints. Facilities are also evaluated for the presence of illicit discharges. All inspections are followed up with correspondence outlining the findings of the inspection and expectations of the industry. Any item where the industry is not in compliance with the permit is highlighted with a deadline to meet compliance before escalating enforcement is pursued. It is the goal of the program to perform annual inspections, at a minimum, of all permitted facilities.

Industries are also inspected if they are identified as potentially needing a permit. These facilities are identified through a systematic search using storm water outfall basins prioritized based on problematic outfalls. The basins are delineated for drainage, the industrial facilities identified within the basin using our database, and facilities selected by SIC Code. Inspections are also performed in response to referrals, drive-bys, complaints, and responses to an industrial survey performed in support of the pretreatment program. Prior to an inspection, building records, existing files from the pretreatment program, and plumbing records are reviewed.

Stormwater sampling of permitted facilities is performed by collecting grab samples at the sample point(s) identified in the facility's SWPCP. Analyses are performed by the City lab. This sampling does not relieve the facility of its stormwater sampling responsibilities. Files are developed on the facilities and maintained separately from the pretreatment files. An electronic database has been developed and is used by both pretreatment and storm water staff.

Enforcement

Enforcement capability was developed in City Code. Where the City does not have enforcement authority, it seeks voluntary compliance and refers enforcement to the permitting authority when necessary.

Funding

The program is entirely funded through a surcharge on the storm water fee for industrial and commercial accounts. The storm water fee is currently based on impervious area. This surcharge also funds portions of other programs that have work related activities because of industrial and commercial storm water discharges. The current staffing level is one supervisor and three technicians. Program costs amount to approximately $280,000 per year. This is primarily composed of salaries and benefits, but also includes approximately $25,000 for sample analyses The budget also contains funds for the development of BMPs and educational materials.

Findings

Legal Authority

It is essential that legal authority be developed in order to be able to implement and support a municipal program. However, what is contained in the enabling legal authority (code) can vary drastically. It is important that the municipal permit holder review the NPDES Industrial Storm Water permit to determine its adequacy in meeting the municipal permit requirements. Most industrial storm water permits are general permits and they may not adequately address issues for which the municipal permit holder is responsible.

For instance, if the municipality is responsible for meeting TMDLs for a particular water body, the industrial permit may not even require that the facility monitor for these pollutants in its discharge. Provisions should be placed in code that allow the municipality to require the facility to conduct this monitoring. Another example would be the requirement to submit SWPCP and monitoring results to the municipality if this is not included in the permit. Nothing in federal regulations prohibits the municipality from requiring additional controls beyond the permit requirements. A review of the industrial stormwater permits can help identify elements that should be included.

Another provision that should be considered is the ability of the municipality to require a facility to obtain a permit. Currently, federal regulations base the requirement for a permit on SIC Code and exposure. There is a caveat that allows the permitting authority to require a facility to obtain a permit regardless of its SIC Code if that facility is impacting water quality. However, this could require that the municipality undertake sampling and additional work to prove an impact. This reduces the efficiency of the program in terms of resources and uniformity. It may even be necessary to include provisions in the code that allow the municipality to develop its own permit. Such a tactic is time consuming, however, and could create confusion for the regulated community.

Memorandum of Agreement (MOA)

The MOA should be developed to clearly outline the responsibilities between the permitting authority and the municipality. Language should be broad enough not to constrict how the municipality implements the inspection and monitoring program. This allows the municipality to alter the program as information is obtained from inspections without having to alter the MOA. Probably the most important element of the MOA is the delineation of enforcement. Since the municipality does not have authority to enforce permit conditions, language should specify that the municipality will enforce applicable requirements of the Code and seekvoluntary compliance where it has no independent enforcement authority. If compliance is not obtained using these methods, enforcement would be referred to the permitting authority.

Inspections

The City has placed the responsibilities for implementation of the program within the Industrial Source Control Division. The section also houses the pretreatment program. It was felt that the responsibilities needed to be separate because of the large number of facilities that are to be addressed. The City has over 24,000 commercial and industrial facilities. Of these, nearly 3,000 have the SIC Code that potentially places them in the permitting program. In addition, a Stormwater Work Group is responsible for addressing other discharges to the MS4, such as pumped groundwater, boiler blow-down, water supply line flushing, washwater, and others.

For the City's situation, this arrangement has worked very well. The Work Group is able to develop expertise in the area while having access to existing information from the pretreatment program. Other municipalities have adopted this approach while others have incorporated the responsibility into the pretreatment program or other existing programs including fire and safety inspections. The municipality needs to consider several items when determining who will be responsible for implementing the program.

- The number and type of industries
- Existing oversight of the industries (pretreatment, hazardous materials,. . .)
- Existing programs within the municipality

If the municipality decides to place the responsibility in a Work Group that is not dedicated for this purpose, it needs to ensure that adequate resources exist to implement the program and meet the conditions of the MOA. The stormwater program may not be the priority of the assigned work section and if resources become inadequate, this work may be viewed as low priority and may not be addressed at the level that makes it effective.

The City has developed several "partnerships" to expand the inspection program. Informational flyers and a poster were developed for county sanitarians to use when they inspect restaurants. A simple storm water checklist was developed for City commercial recycling staff to use when inspecting retail establishments. In both of these cases, it is important to note that the facilities targeted would not ordinarily be inspected for storm water issues (unless a complaint was received) and that any issues of consequence would be addressed by storm water staff.

Permits

The DEQ has been issuing permits since September 1991. When the City took over administration of the permits in the fall of 1994, 63 facilities that discharged to the MS4 had permits. Since that time, an additional 65 facilities have been identified through inspections of non-permitted facilities. Non-permitted facilities are inspected based on SIC Code and prioritized by outfall basins that have been identified as problematic. This approach was necessary due to the large number of industries within the City that have the SIC Code included in the federal regulations. To perform a general survey of all facilities would have generated much more work than resources allowed. Each site would have to be evaluated prior to the issuance of a permit as the City is a mixture of combined sewers, sumps, and separated storm sewers. Staff members spend a considerable amount of time determining where stormwater drainage discharges. A municipality may be able to utilize this approach if the industrial base is smaller. Federal guidance states that a system-wide approach to establishing priorities for inspections should be developed.

Based on inspections of non-permitted industries to date (approximately 15% require a permit), and the remaining facilities that require inspections, it is estimated that an additional 50-100 facilities will be permitted. Based on these numbers, only 25-30% of facilities requiring a permit had applied when the City took over administration of the program. However, a large percentage of the facilities not requiring permits still had issues that needed to be addressed or were given BMPs that they were requested to implement.

SWPCP

The original general permit developed by DEQ did not require that the permit holder submit the SWPCP. When the City took over administration of the permits, the plans were to be submitted using provisions of the City Code. Over 50% of the facilities (33 of 63) had not developed a plan within the 180 days allowed in the permit, and of these, 14 (22%) had not even developed a plan. It is imperative that the municipality includes provisions in the code to obtain these plans if the provision does not exist in the permit. The requirement to submit the plan allows the City to track its development and review the plan prior to an inspection. Currently, only 5% of facilities have not met the requirement to develop the plan in the required time period.

Unfortunately, there is no requirement in the permit that the plans need to be approved. As long as they contain the necessary elements required in the permit they would be in compliance. This has proven problematic in the quality of some plans. It also restricts the City's ability to require that the facility implement certain pollution control activities. This emphasizes the need to include these provisions in the legal authority. The City has taken the approach of strongly suggesting that certain activities be implemented and incorporated into the plan. Once it is in the plan, it becomes part of the permit and provides a mechanism to require the facility to implement these measures. The City is then able to take the position of providing assistance in evaluating compliance with the permit. By noting these deficiencies and seeking voluntary compliance, the City believes it is assisting the industry in meeting the conditions of their permit and benefiting the environment through the implementation of the SWPCP.

Monitoring

When the City took over administration of the program in 1994, monitoring results were requested from permitted facilities. Nearly 60% (36) of the facilities had not performed the required monitoring for the previous year. Of these, 22 had not taken the required two samples, while the remaining 14 did not perform the complete analyses. Of the samples taken, 30% violated standards in the permit. Within the first year, the City was able to raise compliance on sample collection to over 80% and reduce violations of standards from 30% to 23%. Currently, over 90% of the facilities are in compliance with sample collection. It is more difficult to compare compliance with standards because a new permit was issued in 1998, that includes benchmarks for metals that were not in the original permit.

Monitoring results have limitations because they are grab samples taken from a discharge that is short-term in nature and highly variable. However, they can be used as a tool to measure effectiveness of BMPs and to identify sources of pollutants. Based on sample results, the City has identified several classes of industries that pose significant pollution concerns. These are, in order:

- Automotive recyclers (SIC Code 5015) – metals, oil and grease;
- Recycling industry (5093) - metals, oil and grease;
- Transportation facilities (various 4000) – metals, oil and grease, TSS;
- Heavy manufacturing (33--, 34--) – metals;
- Food industry (20--) – TSS, BOD, oil and grease.

Other SIC Code groups either represent a lower threat as a whole or are not present in the MS4. The City is now using this information to reprioritize their efforts in identifying industries that require a permit. While the City is still pursuing efforts based on outfalls, they are also developing a parallel effort to inspect all the facilities in these classes. In addition, investigation efforts by the City identified the Wholesale Distribution of Construction Equipment (5082) and Heavy Construction Equipment Rental (7353) as significant sources of pollutants. These classes are not included in the federal regulations, but any municipal program should evaluate these facilities.

Enforcement

Enforcement capabilities have been developed in code for those discharges to the MS4. However, the City does not have enforcement capability on permit provisions. The City must seek voluntary compliance and refer those matters to the permitting authority for which they don't have enforcement capability. This has worked to date, but requires coordination between the City and DEQ. When seeking voluntary compliance, the City uses the threat of referral to the permitting authority or third party lawsuits to obtain compliance. To make this effective, the permitting authority must be ready to follow up with enforcement upon the municipality referral.

Funding

As with a number of environmental programs, especially regarding storm water, it is very difficult to measure the cost/benefit until the program has been in place for a period of time. Costs have been identified, and certain benefits have been realized. Compliance with permit conditions, for both industry and the City, have been, for the most part, met. However, has this resulted in a benefit to the environment? City data have shown that industrial land use areas have significantly higher concentrations of pollutants than other land uses. Whereas the industrial land area in the MS4 is only 4%, it accounts for 11% of TSS, 15% of oil and grease, and 24% of metals. It would reason that a program aimed at the highest concentration of pollutants would produce a good return on the investment, Another benefit of the program has been the identification and removal of non-stormwater discharges. Approximately 15% of the inspections have identified non-stormwater discharges, primarily washwater, that were of concern.

Conclusions

The development of a program to monitor and control pollutants from industrial facilities is not one of the six BMPs that Phase II permit holders will be required to be developed. This may be due, in part, to the assumption that all industrial permits would be in place because of Phase I requirements. However, our efforts have shown that only 25-30% of the industries requiring permits had applied prior to the administration of the program by the City.

If a municipality decides to develop and implement a program, it is recommended that it utilizes the accomplishments of Phase 1 applicants. Phase 1 applicants can provide inspection forms, BMPs, MOAs, code language, and other necessary components to develop the program. They can also share results of their work to help prioritize the efforts of the municipality and help decide how to incorporate the work into existing programs. A municipality may also become a co-applicant with Phase 1 permit holders. If this occurs, the applicant will become subject to an industrial control program but may be able to utilize the existing program of the permit holder.

If a municipality does not develop a program, it is recommended that it at least work with the permitting authority to identify who has a permit and the status of their compliance. The municipality should also evaluate the industrial base in the MS4 and provide this information to the permitting authority if it identifies a facility that may be subject to the program. It may be prudent to incorporate these activities into the illicit discharge elimination program, which is a requirement of the permit. Whatever the municipality chooses, it needs to understand that it is ultimately responsible for discharges from its MS4.

Lessons Learned from Three Watershed-Sensitive Development Demonstration Projects in the Great Lakes Basin

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Introduction to The Conservation Fund

The Conservation Fund (TCF) is a national, non-profit conservation organization that purchases and protects land – more than 1.6 million acres since 1985. TCF also assists local communities, private landowners and government agencies with programs that balance conservation with economicdevelopment. TCF works with communities to improve water quality, build sustainable economic opportunities, and develop leadership skills, activities that put it at the forefront of conservation across America.

TCF has been active in the Great Lakes Basin since it opened a regional office in 1995. The initial focus of its work was the Great Lakes Watershed Initiative. This basin-wide effort was designed to raise the local visibility of the nonpoint source water pollution issue. The Initiative adapted many of the innovative solutions showcased in the National Forum on Nonpoint Source Pollution. TCF worked with many local partners to launch a network of community-based projects addressing nonpoint source water pollution in urban and rapidly urbanizing areas in eight states and Canada. The Initiative was conducted in partnership with the Council of Great Lakes Governors with major funding from the Great Lakes Protection Fund and Kraft Foods.

TCF expanded several projects as an outgrowth of the Initiative including the watershed-sensitive development work outlined in this paper and a sustainable development effort in Michigan. In Michigan, TCF facilitates a broad, community-based sustainable development effort in the Saginaw Bay watershed. The goal of the initiative, which engages local businesses, community groups, and government agencies, is to better link the environmental and economic well being of Saginaw Bay communities in order to sustain and improve the region's overall quality of life. This year, the project received the National Award for Sustainability from the President's Council for Sustainable Development and Renew America.

Introduction to Conservation Development Project

Currently, TCF is targeting one of the remaining threats to natural resource quality, enhancement, and preservation in urbanizing areas – conventionally designed subdivisions. In partnership with local developers, community groups, and government agencies, TCF is working in the Great Lakes Basin on the Conservation Development project. This project is designed to demonstrate the environmental and economic benefits of watershed-sensitive design through a series of model developments. In particular, we are working to demonstrate the benefits of watershed-sensitive site-planning and best management practices that reduce impervious cover and conserve open space. The current model projects are being developed in Huron, OH, Germantown, WI, and Niles, Ml. The George Gund Foundation and the Great Lakes Protection Fund have provided major funding for this project.

We define watershed-sensitive development to include: open space design, significant reduction in impervious coverage, natural stormwater conveyance and storage to the greatest extent possible, and appropriate construction mitigation measures. Watershed-sensitive design can be used to build the same number of houses and still preserve a significant portion of the subdivision's original landscape. These open spaces serve important community and environmental functions. Agricultural land can be farmed, residents can enjoy recreational and aesthetic benefits, and important natural areas and systems can be preserved. Alternative designs also reduce the amount of impervious cover.

Techniques including narrower streets, porous surface parking areas, stream buffers, and open channelsforstormwater conveyance minimize runoff from new development and its negative impacts on water resources.

When evaluating potential conservation development projects, The Fund considered the following criteria:

- Local community must be interested and open to new techniques, including flexibility on zoning and subdivision code issues;
- Property already slated for development and conventional development would have significant negative impacts on the site itself or adjacent natural resources;
- Project partners represent one of the dominant development paradigms in the Great Lakes (i.e., professional developer building homes in farm fields, lay developer seeking to hold and protect family or other special lands, government agency seeking to encourage sound practices); and
- Project site is suitable for demonstrating broad array of site design techniques and best management practices (BMPs).

Through TCF's work in the Great Lakes, we gathered many lessons-learned that may be applied to other regional and national efforts, This paper will review many of these lessons with the hope that other communities and organizations will be able to benefit from our experiences. The paper is organized into the four sections listed below:

I. Overall Lessons Learned

1. Not "One Size Fits All"
2. Measurable Criteria for Watershed-Sensitive Development
3. Adequate Oversight and Inspection
4. Incentive System Needed
5. Relationship to Other Smart Growth Movements

II. Lessons Learned about the Development Process

1. Pace of Development Often Incompatible with Innovative Site Design
2. A Greater Initial Investment in the Baseline Information is Necessary
3. Initial Cost of Watershed-Sensitive Developments
4. Deed Restrictions
5. Need Additional Lay Developer Education
6. Aesthetics Do Not Equal Ecology

III. Lessons Learned about Engineering/Site Design

1. Educate the Engineers
2. Lot Size Often Dictated by Septic Issues
3. Need Hard Science

IV. Lessons Learned about Working with Communities

1. Community Initiative

2. Local Official Knowledge Varied

3. Strong Local Partner is Key

4. Final Lessons Learned

Overall Lessons Learned

Not "One Size Fits All"

The approach used to create a watershed sensitive development must be tailored to the individual, organization, or developer creating it. The assistance needed by a private landowner that is seeking to preserve portions of family lands, for example, is quite different from that needed by a professional developer. We found that the models we developed need to take the different skills and goals of the project's initiator into account very early in the process. For example:

Lay developers (i.e., the individual landowners), not surprisingly, need help with the business aspects of the project, and are more inclined to make frequent changes to the preliminary site plan and architectural style of the development. These changes often reflect something the developer has "just learned" or "just considered." These new ideas can add value to the project, but they also require the technical assistants (e.g., landscape architects and engineers) to be more patient, more flexible, and firmer than they might be with professional developers.

Professional developers demand immediate turnaround on requests for assistance, and are looking for "the facts" on what is required to make a development watershed-sensitive. They can be somewhat impatient with the notion that there are not a fixed and specified set of best management practices and site design practices that, if employed, will "always" result in an "environmentally friendly" development.

Measurable Criteria for Watershed-Sensitive Development

As we began to design the model projects, it became apparent that there were no specific criteria available to measure the benefits of the watershed-sensitive design. A tool was needed to encourage developers to fashion environmentally friendly site designs, to help communities add flexibility to their local ordinances, and to provide a standard that can be understood by both homebuyers and existing community residents.

In response to this, TCF developed the Conservation Development Evaluation System (CeDES) as a rating system to evaluate a conservation development over the development's lifetime with emphasis on water quality and landscape impacts. The purpose of CeDES is to encourage developers to think about environmental concerns earlier in the planning process and to provide consumers and communities with a means of assessing the impact of better site design practices. It was developed with input from over thirty national professionals skilled in planning and evaluating conservation developments. It may be viewed at http://www.conservationfund.org/conservation/sustain/gloindex.html.

Adequate Oversight and Inspection

One of the biggest challenges is ensuring that the contractors are building in an environmentally responsible manner. Even if the developer is committed to minimizing the impact of the development on the environment, if contractors are not educated and committed it may not happen. This is a challenge for many local agencies and municipalities who have limited staff for constant inspections. Even if the communities have ordinances that require construction erosion controls etc., without constant inspection many contractors do not follow the requirements. The nonpoint source pollution from construction, especially the sediment loadings, can negate any benefits from the alternative site design. One recommendation is for the community to require that an environmental inspector be hired specifically for the site. The inspector may be from a consulting firm or from a local Soil and Water Conservation District.

Incentive System Needed

We expect that this process will proceed much more quickly in communities that have recognized the threats conventional developments pose and have begun developing strategies to address them. In order to expand conservation development practices to a broader constituency, state or county agencies may need to develop incentive programs that prompt local developers to undertake these projects. With each community, we encouraged the creation of incentives for watershed-sensitive development. These included density bonuses for the developer through credits for land preservation and minimization of impervious coverage. We also investigated the use of the Clean Water Act State Revolving Fund (SRF). Among other uses, these funds are used to reduce nonpoint source pollution and could encourage watershed-sensitive development. The State of Ohio has successfully used the SRF for this purpose and we hope to pilot the same use of the SRF loans in other states. Incentives such as Ohio's loan program, coupled with the higher financial returns these developments are expected to generate, are making watershed sensitive developments more the norm in the Great Lakes Basin.

Relationship to Other Smart Growth Movements

There are many "Smart Growth" movements currently being debating and promoted throughout the country. Watershed-sensitive development is just one part of the equation. At times, we were challenged to show how this fits into overall community sustainability efforts. The work that the National Site Planning Roundtable completed to develop "Better Site Design" principles has been invaluable in demonstrating how these different movement can work together (Center for Watershed Protection, 1998). We often say that watershed-sensitive development is one option for Smart Growth but that a community needs to find the correct planning principles to work for their residents and issues. Those in the Traditional Neighborhood Design (TND) movement challenge putting sidewalks only on one side of the street, which we recommend for reducing impervious coverage. We also suggest that if sidewalks are on both sides of the street at least one should be made of pervious materials. There also are environmental groups that challenge us for encouraging greenfield development instead of infill development. Again, watershed-sensitive development is only one option of many and if the market is going to demand suburban fringe growth, at least we can work with the communities and developers to ensure that it is done with maximum possible protection and enhancement of the natural resources.

Lessons Learned about the Development Process

Pace of Development Often Incompatible with Innovative Site Design

The pace of development and the pace of government decision-making often are absolutely incompatible. Developers with outstanding loans on land need to move quickly to ensure a development is economically viable. Government agencies, on the other hand, are very concerned about the impacts of development, but move very cautiously, especially when they are undertaking something new. The result is that it is easier for both government and developer to create conventional, environmentally harmful developments than to do something better.

On the demonstration projects, TCF took special care at the outset of the process to communicate the timelines of each participant to the other. In this way, we hoped to keep the parties from throwing up their hands and giving up. For the region, however, we explored possibilities to get communities to adopt "fast track" approvals for watershed-sensitive communities. The first need is to show municipal authorities that these developments deliver tangible benefits, then we can help them develop mechanisms such as a streamlined review process and updated subdivision and zoning ordinances that encourage their creation.

A Greater Initial Investment in the Baseline Information is Necessary

Before planning a watershed-sensitive development, fairly detailed baseline information including topography, soils, and wetlands delineations is needed. Although developers hope that they get enough of the baseline site information before beginning design work, inevitably the risk/benefit of doing extensive baseline work (e.g., soil borings) may preclude the developer from getting all of the necessary baseline data. The common practice is to use "engineering judgment" based on existing data and extrapolation to the rest of the site. Unfortunately, especially when the drainage plan is an integral part of the initial site design, relying on "engineering judgment" simply is not sufficient. For example, on the Ohio site we relied on the existing soils information to design the swale system. After presenting a preliminary site plan, the developer discovered through additional research and sampling that the available soil information did not accurately represent the existing soil conditions and the drainage plan had to be reconstructed.

Initial Cost of Watershed-Sensitive Developments

Planning and developing a watershed-sensitive development takes time and costs money. Both lay and professional developers often underestimate these initial costs. Professional developers often leave site planning to their engineers. The engineers typically obtain a wetlands delineation and examine soil and topography maps, but do not evaluate the site from a watershed or ecological perspective. Although lay developers may be more familiar with the special features of their properties than professional developers, both need help to catalog all the features and to understand the site's role in the surrounding landscape. Quite reasonably, professional developers often are unwilling to undertake these expenses until they have a sense of the project's scale and niche in the market. We believe, and existing watershed-sensitive developments indicate, that the costs of evaluating a property from an ecological and a watershed perspective will be recovered when the development is sold out.

Deed Restrictions

The deed restrictions (i.e., covenants, conditions, and restrictions) necessary to ensure that the development will continue as a watershed-sensitive development in perpetuity are a lot more extensive than typical deed restrictions. Early in the process, sample restrictions for various developments should be presented to the developer and to the community so that they understand the consequences of using some of the watershed sensitive techniques. The developer will gain an appreciation for the long-term commitment necessary for a successful development and local officials may be put at ease when they recognize that major additional responsibilities (e.g., swale maintenance) rest with the homeowners association and not the local government.

Need Additional Lay Developer Education

Private landowners need to be assisted and educated through the process. Although these initiators often have a deeper environmental commitment than professional developers, they often do not understand what kinds of activities on their properties will have negative watershed impacts. For example, on one of our projects, the lay developer suggested that a pond be built each time an area of low-lying ground is found to be wet most of the year. Once informed about the relationship of these areas to more prominent wetlands on the site, the developer agreed to treat these areas more appropriately (i.e., preserving and enhancing the existing wetlands). The professional developers understand stormwater and wetlands issues better because they operate in the regulatory arena. The lay developers may need to be educated about the significance of these issues and other issues that are common knowledge to professional developers.

Aesthetics Do Not Equal Ecology

Another aspect of landowner education is the principle that aesthetics do not equal ecology. Just because a development preserves or creates attractive green spaces does not necessarily indicate that it is not harmful to the surrounding watershed. Accordingly, the criteria we developed for watershed-sensitive development (see discussion above under Measurable Criteria) incorporate appropriate baseline evaluation of the site to insure key resources are protected, and a thorough analysis of the stormwater impacts after development.

Lessons Learned about Engineering/Site Design

Educate the Engineers

If any of the county, township, or city engineers are not comfortable with the techniques being used, they can turn down the project at any point in the review process. In all three of our projects, the "old-timer-" engineers were extremely conservative and feared change more than any other local officials. We found that the developers' engineers need constant oversight and education to design the sites using the watershed-sensitive techniques. Unfortunately, without a broad effort to educate engineers, they will have to be educated one community or county at a time. Once these techniques become more commonplace, we assume that such a great initial effort will not be necessary.

Lot Size Often Dictated by Septic Issues

Wastewaterissuesoften control the form, location, and economicfeasibilityof a new residential subdivision. In many parts of the Great Lakes region, heavy clay soils strictly limit the functioning of conventional septic systems. For this reason, lot size is frequently dictated by septic issues as much as by local zoning. Although there are some alternate systems (e.g., constructed wetlands and community systems) being piloted and used in the region, local health officials are very cautious about permitting them. This caution arises both from concerns about their technical functioning and about long term maintenance issues. Communities already feel burdened by the need to monitor individual septic systems. They are skeptical about a homeowner association's ability to reliably maintain a community treatment system.

Wastewater treatment issues should be considered up front in evaluating the feasibility of clustering homes on a particular site. If a public sewer does not serve the site, clustering probably will not work as well (i.e., the individual lot sizes will not be able to be reduced as much). There is the possibility of placing the leach fields in the common property to increase the overall open space percentage.

Need Hard Science

Although there is a great deal of national literature detailing watershed-sensitive development techniques, there is not a lot of research documenting the extent of the water quality benefits they provide in the field. The Center for Watershed Protection (CWP) recognizes that there is a lack of water quality monitoring data that evaluates the techniques in varied site conditions and is working to develop and encourage more studies. Through consultation with the CWP, the Northeastern Illinois Planning Commission, and the Wisconsin Department of Natural Resources (WDNR), we found that funding for long-term monitoring of these techniques is scarce. Without this data, many of these techniques may be challenged successfully by skeptical local officials. With the assistance of Old Woman Creek Estuarine Research Reserve, one of our local partners, we are monitoring the water quality at the Ohio site. We hope that they will be able to continue the monitoring after our grants are over. We also are working with the WDNR to secure funding for long-term water quality monitoring at the Germantown site. It is our hope that this information will continue to back up many of the claims of watershed-sensitive development and that funding will continue to support these efforts.

Lessons Learned about Working with Communities

Community Initiative

Without community buy-in and interest in these concepts, even the most enlightened developer is not going to be able to get a project approved. When we first started this project, we thought that the developers were going to be the "hard sell." In two out of three of the communities, it actually has been the communities that needed more education. In the Huron project, the developer was sold on many of the alternative site design techniques until he kept getting negative feedback from the township board. This site was chosen because of the commitment of the developer and the obvious benefits to the surrounding water resources. What was not realized was how much resistance there would be in the political arena. At this project, we had several informal meetings with local officials prior to presenting a conceptual plan, but because the process was developer-initiated, they continued to be resistant throughout the process.

Local Official Knowledge Varied

Municipal, county, and state officials with similar regulatory responsibilities often have very different views about the appropriateness of new techniques. Although there are no hard and fast rules about who is likely to be more progressive, disagreements are common and a primary cause of frustration among developers.

As development is now regulated, it is more expensive and time-consuming for a lay or professional developer to create a watershed-sensitive development. The only way for a developer to address this situation is to inform local regulators and planning officials about the project early on, and to involve them in the process Unfortunately, this involvement will probably not speed up the process for the individual developer, but after a few such projects are launched, we believe the barriers for these kinds of developments will be lowered.

Getting everyone with a regulatory or permitting role on a project involved at the very beginning is absolutely vital. If a project that includes techniques that have not been implemented in the region before gets too far along before all the regulators and municipal officials are brought in, the "stranger to the deal" can feel left out and derail the project. Much of this problem will be allayed once a few watershed-sensitive developments are built, but until then, developers and regulators pushing for these practices need to make special efforts to get everyone to the table early. Of course, this process increases the costs of doing the development initially, but it can keep it from falling apart after significant site planning and related costs are incurred.

Strong Local Partner is Key

Throughout this project, TCF acted as a facilitator between the communities and developers and as a representative of the silent third party, the environment. We believe that as each community begins to look at this type of development, this third party is key to the success of a project. Although there are many merits to approaching communities as a national organization, without a primary local partner who is well-versed in the trials and tribulations of the development process (or willing to learn them), it is difficult to proceed. A preferable arrangement would be a local organization, such as a land trust, leading the effort with support from a regional or national organization or technical assistance center. A local organization will have a greater vested interest in and knowledge of the local environment, will know the local officials and political and personal histories, and will be able to track and monitor the day-to-day activities surrounding the development. In the long term, local land trusts may become a key player in this area. They understand land conservation and watershed issues, frequently have close ties with both local landowners and local government officials, and have some comprehension of the development industry.

Final Lessons Learned

Several realities of the development process that have little to do with the challenges of watershed-sensitive development are important to mention for groups and communities considering this type of project. One is that the personalities and reputations of the developers can make or break a project. On our project in Ohio, the developer apparently had a "history" with several of the plan commissioners. Our partners in the community think that the plan commission and the engineers were being unduly unfair during the review process. Also, one of the developers in Wisconsin has a reputation for "low-end" development. Because of this reputation, the Village is afraid that the developers will do their typical development in their town.

Another reality of the development process is that the Village Planner of Germantown estimated that 60% of submitted development plans are reviewed by the plan commission and less than 50% of zoning requests are approved. All of our projects include a zoning request because the current local ordinances do not include a provision for watershed-sensitive development.

Conclusion

At all three of our model sites there are already signs of new developments being proposed with many of the watershed-sensitive techniques. In Wisconsin, the developer was approached by neighboring communities to design similar subdivisions. In Michigan, several local officials have stated interest in adding language in their new ordinances that would encourage this type of development. In Ohio, our local agency partner, Old Woman Creek National Estuarine Reserve, was approached by a developer who has been watching the process and is interested in using some of the techniques at an adjacent site. While the review processes for all three projects have not been as easy as anticipated, it is expected that the next round of developments will have an easier time because of the trailblazing work done before them.

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Continuous Deflection Separation (CDS) for Sediment Control in Brevard County, Florida

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Abstract

In July 1997, Brevard County's Stormwater Utility Program installed a new type of trash and sedimentation control device called a Continuous Deflection Separation (CDS) unit. This was the first American installation to use the CDS technology, which was developed in Australia. After installation, autosamplers were placed upstream and downstream of the CDS unit and a year's duration of sampling data collected. Monitoring has shown that the CDS unit has provided an average 52% removal efficiency for total suspended solids and 31% removal efficiency for phosphorus.

Introduction

Stormwater sedimentation is a primary source of pollution to Florida's Indian River Lagoon. Suspended solids and turbidity reduce sunlight penetration in the lagoon which negatively impacts seagrass growth. Where land is available, detention ponds effectively reduce most of the suspended solids from stormwater flows. When land is not available, alternative, less effective, treatment methods must be used.

The CDS technology was initially developed in Australia to provide an effective method for trash and solids removal from stormwater flows. The screening action within the unit provides for 100% removal of trash and particles down to 4700 microns. In addition, the unique circular design creates centrifugal action within the round concrete box which propels suspended solids to the center of the box and down into the storage chamber.

Methods

The location chosen for the CDS unit installation was along a ditch at the north end of Brentwood Drive, south of Port St. John. The drainage basin for this location was 24.87 hectares (61.45 acres) in area. This basin has Type A soils along a sand ridge. The land uses are 24.87 hectares (6.7 acres) of roadway (US Highway 1), 8.04 hectares (19.87 acres) of industrial park, 9.47 hectares (23.39 acres) of vacant land, and 4.65 hectares (11.49 acres) of commercial property. The industrial area has a permitted stormwater system. A significant land feature is a 2.02 hectares (5 acre) dirt parking lot, 152.4 meters (500 feet) upstream of the site around a local restaurant. This parking lot has a steep slope and is composed of fine white base material. There is evidence of heavy silt buildup in the inlets and pipes downstream of this parking lot, along US 1.

There is an earthen ditch running eastward 76.2 meters (250 feet) upstream from the project location. At the project site, there is an existing 122 centimeter (48 inch) RCP driveway culvert in the ditch which discharges to a concrete channel running 152.4 meters (500 feet) eastward to the Indian River. The time of concentration to the site is 63 minutes, with a 1 O-year flow of 1,557.2 L/sec (55 cfs) and mean annual flow of 1,177.9 L/s (38.2 cfs). In Brevard County, the 10-year storm is 20.1 centimeters (7.9 inches) of rainfall and the mean annual storm is 13.97 centimeters (5.5 inches) of rainfall. There is no base flow at this location.

A diversion weir 68.58 centimeters (27 inches) tall is placed in front of the 122 centimeter (48 inch) culvert so as to divert flows over 254.8 L/sec (9 cfs) around the unit. In 18 months of observations, the water level has risen over the weir one time.

A 76.2 centimeter (30 inch) concrete pipe was constructed adjacent to the existing 122 centimeter (48 inch) pipe in order to divert flows to the CDS unit. The 76.2 centimeter (30 inch) pipe enters the CDS unit tangentially to start the circular flow within the unit.

The CDS unit consists of three circular, concrete chambers stacked on top of each other. The top chamber, where the water enters the unit, has a 1.524 meter (5 feet) inner diameter and is 188 centimeters (74 inches) tall. The middle chamber has a 2.44 meter (8 feet) inner diameter and is 127.54 centimeters (51 inches) tall. In the middle chamber is a 1.524 meter (5 foot) diameter stainless steel screen matching the walls of the top chamber. The screen has 4700 micron holes to filter larger materials. The bottom chamber has a 1.22 meter (4 foot) inner diameter by a 1.22 meter (4 foot) tall sediment sump.

Water enters the unit in a clockwise rotation. When the water passes through the screen, it flows counter-clockwise between the screen and outerwall until it reaches a 76.2 centimeter (30 inch) concrete pipe. This exit pipe is tangentially placed for smooth exit flows. The elevation of the exit pipe rises 96.52 centimeters (38 inches) from the lower chamber to the outflow channel downstream of the 122 centimeter (48 inch) culvert. This rise in elevation keeps the normal water level in the unit near the top of the second chamber at all times. There is no base flow at this location.

The top of the unit is flush with the surrounding ground and has a 0.91 meter (3 foot) square, lockable, stainless steel access cover. This feature allows for easy access with a vacuum truck for cleaning purposes.

The CDS unit was installed on July 17, 1997. Installation took two days with the precast structures. A large crane was required to lift the chambers into place. A 4.57 meter (15 foot) deep hole was excavated for the structure.

In conjunction with the CDS unit installation, County forces cleaned the ditch upstream of the unit. Two days later, a significant rainfall event occurred and 2,294 kilograms (6,600 pounds) of sediment from the upstream ditch wastrapped in the unit. After that storm, the ditch was reworked and sod was laid. The sod greatly reduced the volume of sediment washing into the unit.

Cleanouts were also performed on November 17, 1997, removing 626.84 kilograms (1,382 pounds) of sediment and 2.88 meters (34 cubic feet) of trash and debris, and again on May 6, 1998, with 998 kilograms (2,200 pounds) of sediment. The solids removed from the unit are taken to the Brevard County landfill for disposal. The volume of water stored in the unit is greater than the vacuum truck capacity, so decanting is performed on nearby sandy soils to avoid a second trip to the landfill for disposal.

Evaluation of the CDS Unit During Storm Events

The intent of the sampling was to evaluate the effectiveness of the CDS unit in removing pollutants from a storm event prior to discharging stormwater into the Indian River Lagoon.

Five storm samples were collected at the CDS unit between April 1998 and March 1999. The storm events occurred after dry periods ranging between 7 and 75 days. Protocol for this program dictated that if the sample collection devices (autosamplers) were triggered at intervals of less than three days between storms, the samples were to be discarded. This situation did not occur during the year, and near-drought conditions were observed in the sample area throughout most of the year-long monitoring program.

Rainfall was measured at the sampling site by a tipping bucket rain gauge, and additional rainfall data obtained from the Orlando Utilities Commission (OUC) power generating plant 5.6 km (3.5 miles) to the north of the CDS installation.

Review of the rainfall data collected indicates that the majority of the water passing through this BMP was from precipitation falling on the upland, 18.72 hectare (46.25 acre) watershed. The variation noted in both coverage and amount of rainfall helps illustrate the localized nature of the storms occurring along the Lagoon coastline. During this sampling period, water flowing off the drainage basin contributed much more flow through the CDS unit than would have been expected based on the rainfall recorded at the sample site.

Samples were collected through the use of automated storm water samplers; one at the inlet and another at the outlet pipe of the CDS unit. All samples, associated blanks, and duplicates were collected in accordance with our state-certified Comprehensive Quality Assurance Plan.

The stainless steel intake strainers for the samples were mounted on the reinforced concrete pipe, slightly off center bottom, and both angled away from the flow. This was to prevent the strainers from becoming silted over by sediments and allow collection of representative water samples. Flow rates during the storm events were measured initially utilizing water level meters (ISCO bubbler type) in conjunction with a 90-degree V-notch weir, but eventually replaced with a Doppler area-velocity flow meter which provides a more accurate flow assessment. Initially, two bubbler meters were installed with both bubbler tubes mounted on the upstream weir. However, this led to difficulties in estimating just when to trigger (time delay) the downstream sampler in order to collect samples from the same "plug" of water.

During the first three sample events, water levels recorded were correlated to flow, and the samples were manually composited to give a flow-weighted composite sample from each sampler. Both inlet and outlet sample sets were composited identically, in accordance with the EPA NPDES Stormwater Sampling Guidance Document (July 1992). Discreet samples were collected for the fourth and fifth events.

It was intended that the third sample event would include a mass balance calculation. The CDS unit sump was thoroughly cleaned utilizing a VAC-truck to ensure that the material collected was a result of the one storm to be evaluated. Inlet and outlet stormwater composite samples were again collected, with the addition of a sediment (Table 1) and water column sample from the sump. Sediment depths were measured at five locations; four from the corners of the lid opening and one in the center. Based on a depth of 13.21 centimeters, a sump diameter of 1.22 meters (4 feet) and an estimated 1,410.6 kg/m3 (88 lb/ft^3), (based on previous sediment weight evaluation), approximately 217.3 kilograms (479.2 pounds) of sediment was collected in the unit from storm three. Based on the concentrations measured, 126.07 grams (4.443 ounces) BOD 5, 33.587 grams (1.184 ounces) of metals, and 122.81 grams (4.33 ounces) of Total Kjeldahl Nitrogen (TKN) were removed.

Table 1. Sediment Chemical Analysis For Storm **#1**

Parameter	Sediment Grab	Grab Duplicate	Average Value	Detection Limit	Units
Arsenic	0.096	0.11	0.103	0.069	Mg/Kg
Barium	3.4	2.9	3.15	0.14	Mg/Kg
Benzo(b)fluoranthene	260	ND	250	240	Ug/Kg
BOD5	650	510	580	2.7	Mg/Kg
Cadmium	0.03	0.033	0.0315	0.014	Mg/Kg
Chromium	1.1	1.1	1.1	0.027	Mg/Kg
Copper	1.2	0.95	1.075	.0.027	Mg/Kg
Iron	220	260	240	0.55	Mg/Kg
Lead	2	2.2	2.1	0.041	Mg/Kg
Nickel	0.4	0.36	0.38	0.069	Mg/Kg
Silver	0.16	0.059	0.1095	0.014	Mg/Kg
Total Kjeldahl Nitrogen	450	680	565	37	Mg/Kg
Total Phosphorus	79	230	154.5	9.2	Mg/Kg
Zinc	14	14	14	0.27	Mg/Kg

Notes:
Equipment Blank Water Yielded ND for all listed analytes.
*The benzo(b)fluoranthene mean value was calculated with the RDL as the lower value for the duplicate.

Only parameters with values above detection limit are listed. Many others were tested below detection limits.

For this third sample event, the upstream, or intake flowmeter bubble tube was mounted on the 90-degree V-notch inlet weir, as it was for previous sample events. The downstream bubbler, however, was moved and attached to the downstream discharge pipe. This change was necessary to account for the lag time between when the first sampler received flow at the beginning of the storm, the time required to fill the sump with 8,115 liters (2,144 gallons), and discharge to flow past the second sampler several minutes later. The problem encountered with this revised setup was that the upstream V-notch weir used to determine the flow was overtopped, allowing flow around and over it, preventing an accurate flow measurement. This led to disparity in the estimation of actual flow through the unit. Due to the questionable flow measurements, it was not possible to calculate the mass balance.

For the fourth sample event, an ISCO Doppler area-velocity flow meter was mounted in the bottom of the outfall pipe of the CDS unit. Upon registering a water level rise of one inch, this unit triggered both upstream and downstream autosamplers. The autosamplers were synchronized, collecting a bottle set in each ISCO at the same time. With this methodology and placement, overtopping the weir, flow bypassing, and pressurization were no longer potential sources of error. Since the samplers now triggered only when the sump was full, it was also somewhat easier to accept the premise of "what went in, must have come out."

Appropriate trigger points were selected in orderto allow sufficient water depth forthe velocity meter probe to operate properly. We found that the Doppler area-velocity flow meter probes appear to function erratically when covered by less than one inch of water, and believe that measurements taken when the water was at this depth are suspect. Two-bottle sample sets were collected at sampler initiation, and at 1 O-minute intervals during the storm. During previous sample excursions, samples were manually cornposited. Due to a high suspended solids content, (heavy particles including sand) that rapidly settled in the sample container, it was questioned whether the composite samples were truly representative of the solids collected. Therefore, discrete two-bottle sets collected every 10 minutes were sent to the laboratory without being cornposited.

For the fifth sample event, two-bottle sample sets were again collected at sampler initiation, and at lo-minute intervals during the storm. As with the previous sample event, sample sets were not composited but sent for analysis as six individual, two-bottle sets. The sample bottles for bottle sets six were not collected due to insufficient water to cover intake strainers, as the storm was not of adequate duration to produce the last 1 O-minute sample. Because of numerous problems encountered in the previous storm event samplings, along with refinements in sampler setup and flow measurement, the fifth storm sample event is considered the most accurate to determine what pollutant reduction is provided by the CDS unit for that storm. The individual two-bottle sets showed the variation in pollutant loadings throughout the storm event and the corresponding removal under the varying loads. Unfortunately, this was the lowest flow storm encountered, which may account for higher than normal removal efficiency. Maximum flow was estimated to be only 136 liters/sec (2.16 gpm). The average pollutant reduction between inlet and outlet samples for this event was: BOD5 53%, COD 52.6%, TP 36%, TSS 56%, and Turbidity 74.8%.

Sample results are presented in Tables 2 through 4 for the five sample events. Storm event 2 showed a 23% reduction in turbidity, but no reduction in the other parameters. Storm 4 showed an increase in most parameter concentrations between inlet and outlet that could not be attributed to resuspension due to a full sump, since the sump had been cleaned prior to the third event. Data for these two storms are therefore suspect. For events 1, 3, and 5, the average removal efficiencies for those parameters that showed a reduction were: TSS 52%, Turbidity 46.9%, BOD 34.2%, COD 35%, and TP 30.6%

After each sample event, field observations were made of the appearance of the sample jars, each containing a water sample that had been collected at progressive ten-minute intervals throughout the storm flow. Outlet samples typically appeared to be less turbid than the corresponding inlet samples, and also had less sediment on their bottoms. An observation was also made of the water surface inside the CDS unit proper. There was typically a thick layer of floating grass and other vegetation, an oil sheen, glass and plastic bottles, plastic sheets and bits, seeds and nuts, sticks, and a surprising amount of Styrofoam cups and particles.

Table 2. Storm #1-#3 Test Results - Composite Samples

STORM 1	pH s u	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	220	180	28	150	1.4
CDS Outlet	7.4	110	100	23	110	1
Change	0.2	100	80	5	40	0.4
Percent Reduction	3%	50%	44%	18%	27%	29%

Maximum flow rate = 5.488 literslsec (87 GPM, 0. 19 cfs)
Storm Duration = 67 minutes
Rainfall @ OUC 0.254 cm (0. 1 inch), @ SITE not recorded

STORM 2	pH s u	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	8.4	350	440	8.2	20	0.86
CDS Outlet	8.2	350	340	8.2	20	0.86
Change	0.2	0	100	0	0	**0**
Percent Reduction	2%	0%	23%	0%	0%	**0%**

Maximum flow rate = 8.39 liters/sec (133 GPM, 0.3cfs)
Storm Duration = 68 minutes
Rainfall @ OUC 1.778cm (0.7 inch),.@ SITE 0.0762 cm (0.03 inch)

STORM 3	pH s u	Total Suspended Solids(mg/1)	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	300	110	12	71	1.3
CDS Outlet	7.6	150	86	8.2	53	0.95
Change	0	150	24	3.8	18	.35
Percent Reduction	0%	50%	21.8%	31.7 %	25.4	27%

Maximum flow rate = 149.75 liters/sec (2374 GPM, 5.29cfs)
Storm Duration = 113 minutes
Rainfall @ OUC 4.064 cm (1.6 inch), @ SITE 1.27 cm (0.5 inch)

Table 3. Storm #4 Test Results - Discrete Samples

Set 1 @ initiation	BOD5-Day (mg/1)	COD (mg/1)	pH (SU)	Total Phosphorous (mg/1)	Total Suspended Solids (mg/1)	Turbidity (NTU)
Inlet 1	2.1	2	8	0.32	690	99
Outlet 1	5.4	2	7.8	0.19	320	120
Change	+3.3	0	-0.2	-0.13	-370	+21
Percent Reduction/Gain	+61%	0*%	-3%	41%	-54%	+18%
Inlet 2	6.6	15	8.3	1.2	1400	1800
Outlet 2	7	18	8.4	0.94	1600	1000
Change	+0.4	-3	+0.1	-0.26	+200	-800
Percent +/-	+6%	+17%	+1%	-22%	+13%	44%
Inlet 3	6.7	25	8.2	1.2	830	530
Outlet 3	6.7	24	8.3	1.5	550	430
Change	0	-1	+0.1	+0.3	-280	-100
Percent Reduction/Gain	0%	-4%	+1%	+20%	-34%	-19%
Inlet 4	6.3	45	8.1	1.6	330	200
Outlet 4	NT	NT	NT	NT	NT	NT
Change	Na	Na	Na	Na	Na	Na
Percent Reduction/Gain	Na	Na t	Na	Na	Na	Na
Inlet 5	5.6	33	8	1.6	290	300
Outlet 5	6.4	30	8.2	1.6	170	260
Change	+0.8	-3	+0.2	0	-120	40
Percent Reduction/Gain	+13%	-9%	+2%	0%	41%	-13%
Inlet 6	6	39	7.9	1.6	220	120
Outlet 6	6.3	33	8.2	1.5	270	230
Change	+0.3	-6	+0.3	-0.1	+50	+110
Percent Reduction/Gain	+5%	-15%	+4%	-6%	+19%	+48%

Maximum flow rate = 60.30 liters/sec (956 GPM, 2.13 cfs)
Storm Duration = 55 minutes
Rainfall @ OUC 2.794 cm (1 .1 inch), @ SITE 0.006 cm (0.002 inch)

Table 4. CDS Storm #5 Test Results - Discrete Samples

	BOD5-Day (mg/1)	COD (mg/1)	pH (SU)	Total Phosphorous (mg/1)	Total Suspended Solids (mg/1)	Turbidity (NTU)
Inlet 1	4.6	68	7.8	0.23	49	16
Outlet 1	4.0	18	7.9 1	0.18	11	4.3
Change	-0.6	-50	+.1	-0.05	-38	-11.7
Percent Reduction/Gain	13%	74%	1 %	22%	78%	73%
Inlet 2	10	51	7.8 1	0.25	59	38
Outlet 2	3.8	23	7.9	0.18	19	6.9
Change	-6.2	-28	+.1	-0.07	-40	-31.1
Percent	62%	55%	1%	28%	68%	82%
Inlet 3	13	55	8.2	0.3	23	23
Outlet 3	4.7	33	7.6	0.18	21	12
Change	-8.3	-22	-0.6	-0.12	-2	-11
Percent Reduction/Gain	64%	40%	7%	40%	9%	48%
Inlet 4	9.9	53	9.2	0.35	39	61
Outlet 4	3.9	29	7.7	0.18	15	7.2
Change	-6	-24	-1.5	-0.17	-24	-53.8
Percent Reduction/Gain	61%	45%	16%	49%	62%	88%
Inlet 5	9.6	53	9.4	0.29	35	56
Outlet 5	3.4	27	7.6	0.17	13	9.4
Change	-6.2	-26	-1.8	-0.12	-22	-46.6
Percent Reduction/Gain	65%	49%	19%	41%	63%	83%
Average Percent Change	53%	52.6%	- %	36%	56%	74.8%

Maximum flow rate 0.136 liters/sec (2.16 GPM, 0.005 cfs)
Storm Duration =50 minutes
Rainfall @ OUC 1.016 cm (0.4 inch), @ SITE, 0.5842 cm (0.23 inch)

Conclusions

While none of the sample events were a perfect combination of a good flow and everything working right, the data collected, and our observations, certainly indicate that the CDS unit is operating as intended and removing significant quantities of debris and suspended materials prior to discharge to surface waters. It was quite impressive to prevent this trash and sediment from washing out into the lagoon during a normal rain.

The phosphorus removals observed for the CDS Unit, as with any BMP of this type, will not have a high degree of accuracy, due to leaching of nutrients from grass, leaves, and other organic debris. If there are no base flows, these leached nutrients will be washed out with runoff and skew sample readings. A much more comprehensive analysis is available in the library of the web site www.stormwater-resources.com.

Future Evaluations

More data are necessary to further evaluate this BMP. Due to the inherent inaccuracies in water quality sampling, additional determination of the efficiency of this type of BMP could be made by conducting a mass loading and sediment evaluation. Much of the sediment collected in this type of BMP is invisible to current testing techniques since it is comprised of large particles that roll along the bottom of the pipe. Yet, known quantities of sediment are being collected.

A previous study of baffle boxes resulted in the same conclusion. Future sediment analysis from the CDS unit could be compared to the baffle box data previously collected. Brevard County will be conducting a sediment evaluation at three baffle box sites over the next 12 months that will provide additional comparison. As time permits, Brevard County will also collect additional sediment data from he CDS unit.

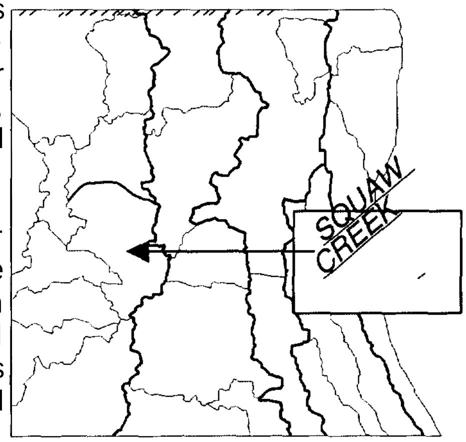
Use of Automated Technologies in Watershed Management Planning

Lake County Stormwater Management Commission (SMC)
Libertyville, IL

Introduction

The Lake County Stormwater Management Commission's (SMC) is working with many agencies to develop comprehensive watershed plans. These watershed plans involve data collection and collation, problem analysis, alternative solutions identification and action plan development. The watershed assessment includes hydrologic and hydraulic modeling; floodplain and floodway mapping; and water resource assessment. As part of a watershed management plan, one of the end results is to update floodplain maps and to map depressional storage areas. Other end products of this effort include location maps of water resources, including wetlands and regional detention sites, with identification of those needing preservation, enhancement or restoration. With this information, projects can be prioritized and cost estimates determined in order to assist local governments in implementing the action plans.

Lake County, Illinois is located in the northeastern corner of Illinois and is one of the fastest growing counties in the country. The county has 61,000 acres of wetlands (12) and 400 miles of streams and rivers throughout its 480 square miles. The combination of growth and the need to protect natural resources is driving the Lake County Stormwater Management Commission's (SMC) comprehensive watershed planning efforts. Plans are currently being developed for urbanizing watersheds between 2 and 50 square miles in area.



Map 1: Lake County, Illinois, Sub-Watershed

With limited personnel and funding, SMC is utilizing in-house computer capabilities and staff technical expertise to save time and money as we increase our ability to model and display watersheds. The Squaw Creek Plan is an example of how SMC is currently utilizing automated technology for watershed planning purposes. The Squaw Creek watershed is 25.5 square miles and is 75% undeveloped (includesagriculture, vacant and open space). The watershed is 17.3 percent wetlands. TheNorthern Illinois Planning Commission forecasts a 155% population change between 1990 and 2020. The Squaw Creek Watershed is located in the western portion of the county and drains into Fox Lake, on the Fox River.

SMC is integrating Geographic Information System (GIS) (2) technology with Computer Aided Design (CAD) and the Army Corps of Engineer's HEC-1 (10) and HEC-RAS (11) models to create an "automated" watershed closely resembling the existing Squaw Creek watershed characteristics. SMC used a variety of vendor software packages that include Environmental Systems Research Institute, Inc.'s (ESRI) ArcView (1) and its Spatial Analyst and Hydrologic Extensions, and Bentley's MicroStation.

Data Collection

It is very important to determine the methodologies for collecting, calculating, and analyzing data early in the automation process. Methodologies were determined for mapping floodplains, inventorying and analyzing water resources (8), and estimating runoff water quality. The floodplain mapping variables included time of concentration, precipitation runoff, stream storage, stream routing, sub-basin boundaries, and water surface elevations. Thesevariables had to be determined before final data could be formatted and collated. We also had to determine how data could be documented in the report early in the study process,

Since considerable map data was available digitally, it was economical to perform many tasks on the computer rather than on hard copy. The Northern Illinois Planning Commission (NIPC) provided the digital land use map. Lake County Map Services provided digital copies of the Soil Conservation Service (SCS) hydrologic soil groups (HSGs) map, hydric soil map, United States Geological Society (USGS) orthophotos, Lake County Wetland Inventory boundary map, and Lake County parcel boundaries. In addition to this digital data, SMC contracted to obtain 2-foot topographic contours, detailed orthophotos, stream cross-sections, and field-surveyed hydraulically significant structures. Bridge and culvert information and stream cross-sections were also delivered digitally from Illinois Department of Natural Resource's (IDNR) land survey crew using Global Positioning System (GPS) and conventional surveying. Photogrammetry and cross-section control points were collected in the field utilizing a GPS with accuracy of 1:50,000 horizontal and +/- 0.03 feet vertical (5). Each USGS digital orthophoto map covers one quarter of a quadrangle and used 45 MB of computer storage. The topographic maps weredelivered in GIS and CAD formats. Contracted data were delivered by square mile. This created a reasonable size data file, including:

Two foot topographic contours and breaklines	1.2 to 3 MB per square mile.
Orthophotos	35 MB per square mile
Digital Elevation Model	1 MB per square mile

The cost for the two foot contours overlaid on an orthophoto varied between $2200 and $3300 per square mile. Additional record drawings of hydraulically significant structures, such as road crossings and detention basin outlets, were collected from county and state highway departments and local communities. The townships and communities seldom had detailed information, so field investigations were undertaken, where necessary, using topographic mapping to establish a reference elevation.

The water resources inventory included a stream assessment, wetland inventory, and a wetland restoration assessment. The stream assessment data were collected in the field along with short community interviews. The stream inventory used an existing methodology created by NIPC (8). SMC created a methodology to identify potential wetland restoration locations.

Surface runoff water quality was estimated using typical measured pollutant loading data for several general land uses. NIPC had an existing procedure that assigned non-point runoff pollutant loads to general NIPC land uses. The typical pollutant loadings were entered into a worksheet so this procedure could be automated.

Creating Hydrologic and Hydraulic Data

Several hydrologic and hydraulic parameters and other data were used to analyze the surface water runoff and generate floodplain boundaries. These included delineating sub-basin boundaries; determining a runoff curve number, time of concentration and Clark's coefficient of runoff for each sub-basin; calculating reservoir data; formatting HEC-1 model; and creating HEC-RAS model geometry.

Sub-basin Delineations

The sub-basin boundaries were produced automatically using the following steps. First, a Digital Elevation Model (DEM) was produced from photogrammetry by a consultant. A DEM is a list of equally spaced data points with a defined easting, northing, and elevation. A spacing of the DEM points of 10 and 30 feet was evaluated. The lo-foot spacing would slightly increase the accuracy of the automated sub-basin boundary's but it used ten times the disk storage as the 30-foot spacing. Therefore, a 30-foot grid DEM was used to determine the sub-basin boundaries due to storage space limitations. Second, the DEM was loaded into ArcView and converted to a DEM grid using ArcView's Spatial Analyst. Third, the flow paths and the preliminary sub-basin boundaries were created using ArcView's Spatial Analyst and Hydrologic Extension along with the DEM grid, which delineated 180 preliminary sub-basin boundaries in 2.5 hours.

Fourth, these preliminary boundaries were edited with the digital contour map in the background to better model storage areas and road crossings. This editing entailed splitting basin boundaries and joining basins together to produce more accurate boundary lines. Editing was performed on portions of approximately 50% of the preliminary sub-basins that were automatically created and ultimately reduced the number of sub-basins. Edited boundaries were checked against hard copy maps and a field investigation of storm sewers and field tiles. A check of maps and field investigation identified three boundaries that needed additional modifications including the addition of one sub-basin. Finally, ArcView was used to automatically calculate each sub-basin's area and a sub-basin identification was assigned to each of the 140 sub-basin areas.

Runoff Curve Number

SMC created a methodology to estimate precipitation runoff. This required converting SMC defined land use categories to Soil Conservation Service (SCS) runoff curve numbers (RCNs) (9) using ArcView and Excel (6). RCNs were calculated using the following sequence. First, the 1990 NIPC land use polygons were converted to SMC land use categories based on land cover using 1996 orthophotos as a backdrop. Land cover was divided into six categories: 1) impervious, 2) graded grass, 3) natural grass, 4) graded forest, 5) natural forest, and 6) agriculture. Typically graded grass and graded forest land cover categories have increased runoff compared with their natural conditions as soils are compacted and depressions are removed during grading. A SMC land use was created for the calibration year of 1996 and for the model year of 2000. Second, concurrently with the land use conversion, the digitally mapped soil numbers were converted to HSGs using GIS queries. Third, the HSG map was intersected with the SMC land use categories to automatically create a land cover map. Fourth, the land use categories table and a land cover conversion table were joined so there was one RCN for each of the four HSGs.

Runoff Data

HEC-1 requires specific input data to generate runoff volumes for each sub-basin. The minimum input parameters for each sub-basin were identification, area, the time of concentration (Tc), Clarks Coefficient of Runoff(R), and weighted RCN. Sub-basin area was delineated as previously described.

The weighted RCN was determined in two steps. First, intersecting the finalized sub-basin boundaries with the RCNs boundaries using ArcView. This splits the RCN polygons with the sub-basin boundaries. This calculation took just twenty minutes. Then this table of RCN attributes for each sub-basin was exported from ArcView into Excel where the weighted curve number for each sub-basin was calculated in one day.

In addition, each sub-basin requires a length and slope of travel to generate the Tc and R. To determine the length and slope, a line with two points were needed, one upstream and one downstream. The line represented the direction of runoff from the farthest ridge to the outlet of the sub-basin. GeoAnalytics, Inc., a consultant, created a program to automatically generate a distance point 10% and 85% from the sub-basin outlet along this digitized line in 30 seconds. The point locations along the line were determined by the methodology used to estimate Tc and R. These points were queried individually with the DEM grid and checked against the topographic map to determine their elevation, which was entered into a table, ArcView calculated all sub-basin line lengths in less than a minute. The stream line and its two elevation points were associated with the sub-basin identification throughout this process. Next, the sub-basin boundaries, the associated line, and two points were joined into one table and exported as a database file. This database file was imported to an Excel worksheet where the slope, Tc, and R were calculated for each sub-basin.

Reservoirs

To model reservoir routing, the reservoir volumes were determined using ArcView and the 2-foot digital contours. The reservoirs consisted of a series of polylines in ArcView after conversion of the CAD contour map. The polylines were modified so they were completely connected and then converted to a polygon in ArcView. This documented the location of every reservoir that was modeled explicitly, as not all reservoirs could be modeled within the scope of our project. Second, the elevation for each contour was entered into a table. The topographic contractor now performs steps one and two. After all the elevation polygons were created, ArcView calculated the area of the polygons with one command.

Finally, the elevation and area tables were opened in an Excel worksheet to calculate the elevation versus storage relationship. This worksheet was referenced by the HEC-1 formatted worksheet described in the next section. Stage versus discharge relationship was determined for each reservoir when data was available using HEC-RAS or HY-8.

Hydrology Model Development

All of this data was combined into one Excel workbook to generate the input needed for HEC-1. The sub-basin data entry included: identification, area, weighted RCN, Tc, and R. Most sub-basins also needed reservoir or stream routing data. An Excel worksheet was edited with HEC-1 formatted column widths so the data could be saved into a file that the HEC-1 FORTRAN program can accept. Sub-basin data were entered automatically by referencing other worksheets in the same workbook. Once the first sub-basin referenced the other worksheets properly, the first formatted sub-basin data were copied to create another set of HEC-1 data for the next sub-basin. After the sub-basin identification was entered for this new HEC-1 input data set, the remaining data were automatically retrieved in the worksheet and correctly formatted, to avoid data translation errors.

Hydraulic Data

The stream cross-section data were initially generated in MicroStation. Each section was digitized as a series of connected line segments that were exported to a comma-delimited file of easting, northing, and elevation which was then imported into HEC-RAS's "Import/Export Files for Geospatial Data." The culvert and bridge data had to be coded in separately. The channel stationing was determined automatically using Intergraph In-Roads. This procedure not only provided data formatted to be exported directly in HEC-RAS, but also created a 3D map of the channel cross-sections and stream centerline to document the model spatially using MicroStation and ArcView. The cross-section segments had to be manually identified for use in the automated floodplain mapping.

Floodplain Development

Stream cross-sections and hydraulic structures were modeled using HEC-RAS to determine the water surface elevation along the stream. ArcView's Spatial Analyst Extension or Arclnfo could be used to delineate the floodplain from the HEC-RAS output. Final maps were generated in ArcView.

The HEC-RAS generated water surface profiles were exported by HEC-RAS's "Import/Export Files for Geospatial Data." GeoAnalytics Incorporated, Madison, Wisconsin, imported this data into an Arclnfo project that uses a 1 O-foot DEM grid. Arclnfo needs a line and an elevation for each cross-section to map the floodplain. The cross-section line and its identification were created in MicroStation, exported as comma delimited points, and then referenced into ArcView to create the cross-section line. The line with its cross-section identification was associated with the water surface elevation. The grid was then "flooded" between the two cross-sections with a linear slope between the appropriate water surface elevations. This creates a grid of the flooded area. For each flood profile that was to be mapped, a separate grid of the flooded area must be completed.

Reservoirs, such as lakes, ponds, and depressions, that have their Base Flood Elevations determined using HEC-1, were mapped automatically. The storage areas had the water surface elevation defined using HEC-1 then the grid was "flooded" for all points at or below that elevation.

The flooded grids were then converted to polygons and "smoothed" in Arclnfo for use in ArcView. Last the polygons were reviewed against the digital two-foot contours and adjusted as needed before final map production. Every reservoir outlet had to be manually mapped between its outlet and the downstream reservoir or stream floodplain.

Water Resource Assessments

A water resources inventory was completed that included a stream assessment, a wetland inventory, and potential wetland restoration site identification. All of the stream assessment data were collected in the field along with short community interviews and entered into a database. Several key stream characteristics were mapped using GIS. The stream inventory data were queried for specific stream conditions and key characteristics were mapped such as degree of bank erosion or sediment accumulation.

A county wetland Advanced Identification (ADID) study was completed in 1992 prior to the assessment. One of the criteria reviewed for each wetland was its storage potential, which was related to the area of the wetland. Querying the spatial data for specified wetland areas and creating a new set of data easily identified these wetlands. The wetland restoration and mitigation bank site identification methodology was developed by SMC in 1999. Several data sets were queried to identify the former wetland sites that have the greatest number of characteristics necessary to make them restorable and usable as a wetland bank. A less stringent set of criteria was used to define all former wetland sites with restoration potential. The potential wetland restoration sites included all Advanced Identified (ADID) wetlands. Potential wetland banking sites excluded ADID wetlands and restorable sites less than 20 acres.

Surface water quality 'hot spots" were estimated using non-point pollutant loading rates for several general land uses via NIPC methodology. Twelve pollutants were evaluated. The pollutant "hotspots" analysis employed land use, impervious surface area, annual runoff coefficients, and storm sewer conditions as surrogates to determine the annual pollutant loading by sub-watershed. The pollutant loading database was attached to the land use map database. It was then mapped in ArcView resulting in 12 maps, one for each pollutant.

The watershed advisory committee and NIPC identified which level of pollutant loadings should be labeled as detrimental. The pollutant load data were then grouped, using natural breaks in the data set, as low, medium or high. These were mapped and queried to determine where water quality enhancement projects would be most beneficial and highest priority.

Summary

The Lake County Stormwater Management Commission has invested a significant amount of time and funding in developing the hardware, software, and database necessary to perform floodplain analysis. By making this commitment and establishing the methodologies for manipulating data and analyzing watershed parameters, we have created a powerful analysis tool. Mapping accuracy, display flexibility and a wide range of GIS analysis ability has been created through this process. This technology coupled with other resource assessment efforts has created a strong foundation for future watershed planning in this watershed. The technology is transferable and will be used throughout Lake County as our agency resources allows.

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Sediment and Runoff Control on Construction Sites Using Four Application Methods of Polyacrylamide Mix

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Abstract

Fifteen small bare plots (1 meter x 1 meter) on a 10% slope were analyzed for runoff and sediment yield on a construction site. A rainfall simulator applied 6.32 centimeters of rainfall per hour to each plot after a polyacrylamide mix (PAM-mix CFM 2000*) treatment was applied. The following treatments: No PAM-mix applied to dry soil (control), PAM-mix in solution applied to dry soil, dry PAM-mix application to dry soil, PAM-mix in solution with mulch/seeding applied to dry soil, and PAM-mix in solution applied to moist soil. Each treatment was repeated on three plots. When a solution of PAM-mix with mulch/seeding was applied to dry soil and compared with the control (no PAM-mix application to dry soil), we found an average reduction of 93% in sediment yield. An average reduction of 77% in sediment yield was the worst performing PAM treatment, and occurred when PAM-mix in solution was applied to moist soil. The application of dry PAM-mix to dry soil reduced sediment by 83% and decreased runoff by 16% when compared to the control. Our results show that regardless of the application method, PAM-mix was effective in reducing sediment yield in the test plots. The ease of application, low maintenance, and relatively low cost associated with PAM make it a practical solution to the costly methods being implemented today

Keywords:

Soil binders, soil erosion, polyacrylamides, flocculation, infiltration, water retention.

*Use of a product name is for the convenience of the reader and does not imply endorsement by the authors, Dane County Land Conservation, or the University of Wisconsin.

Introduction

One effect of rainfall is the initiation of the erosion process where individual raindrops fall and impact the soil surface. Soil detachment and particle transport by raindrop splash can lead to serious soil deterioration. Once soil is eroded and transported by surface runoff to lakes, rivers, and streams, a degradation of the aquatic habitat occurs. Sediment is the largest pollutant, by volume, in the State of Wisconsin (WDNR, 1994). In order to maintain a healthy watershed, it is critical to control erosion and sediment yield.

Maintaining soil structure and aggregate stability helps control erosion by increasing infiltration and maintaining less erodible-sized aggregates. Stable soil structures also help maintain a healthy environment. The use of polyacrylamides and polyacrilamide mixes (PAMs and PAM-mix) is a new tool to help maintain soil aggregate stability and reduce erosion caused by surface runoff. Such materials can be applied at a rate of 20 to 30 lbs per acre on construction sites, to stabilize such sites against erosion until they can be permanently protected through vegetation.

Water-soluble polymers and water polymer mixes do not create aggregates when applied to soil. However, they can stabilize existing aggregates when the aggregates are saturated with a solution of water soluble polymer mix. Increasing the aggregate stability with polymers reduces the effect of raindrop impact on the soil, thereby reducing erosion. Polymer application to the soil may also retard surface sealing, reduce particle soil detachment, reduce sediment in suspension, and compensate for low residue.

Objectives

The objectives of this study are to determine the optimum application methods and the effectiveness of the PAM-mix under moist and dry soil conditions. The different application methods were applied to a construction site in Middleton, WI. Data were collected to determine the most effective method of application and the effectiveness of the PAM-mix on construction sites.

Literature Review

The use of polymers as soil conditioners has been studied for decades. The most conclusive studies, done by Lentz et al. (1992), determined that negatively charged PAM is an excellent soil erosion deterrent for furrow irrigated fields. It was found to be a cost-effective and safe technology. Sojka and Lentz (1994) found that PAM, when applied in irrigation waters at rates greater than 0.7 kg/ha, reduced furrow erosion by an average of 80 to 90% and increased infiltration on Portneuf silt loam by an average of 15%. Trout et al. (1995) reported a 30 to 110% increase in cumulative infiltration. Roa et al. (1996) found that soils treated with PAM had infiltration volumes more than double that of untreated soils over a two-hour period. The infiltration volumes for the untreated soils averaged 231 ml/38.5 square centimeters while those for treated soils averaged 490 ml/38.5 square centimeters, or 98% of the volume of water to be infiltrated. Roa et al. (1996) also found that the high infiltration rate of the treated sample was associated with low concentration of sediment in the effluent or infiltrated water.

Nadler et al. (1994) found that PAM mobility in sandy loam, as well as clay loam soils, was limited to the top 25 cm 10 months after application. Clays were attached to anionic polymers more easily when salts were present in solution. With anionic polymers, flocculation was easier and more complete. When polysaccharides are present with anionic polymers in solution, fixation was also easier and more complete. Khamraev et al. (1983) reported that clay fixation is best achieved for PAMs with 30% anionic charges. The cementation provided by the clay flocculation stabilizes the aggregate at the surface. Roa et al. (1997) found that using polysaccharides, a calcium source with anionic polymers orpolysaccharides with calcium nitrate and anionic PAM, increased the infiltration rate in saturated cores 5 times greater than with no soil treatment.

PAM use for erosion control provides a potent environmental benefit by halting furrow erosion by about half a ton of soil per ounce of PAM used. PAMs remove most sediment, phosphorus, and pesticides from return flows, and greatly reduce return flow BOD (Sojka and Lentz, 1996). The consequences of reducing sediment and nutrient loading of construction areas can ultimately be expected to reduce the frequency and intensity of algae blooms and reduce turbidity and sedimentation of stream channels.

Lentz et al (1992) in Kimberly, Idaho, reported that when applied at 10 ppm, PAM provided a 94% reduction in runoff-sediment in three years of testing. When used properly, PAM has no measurable toxicity to humans, plants, or aquatic organisms. Molash et al. (1997) state that the Polyacrylamide Allocation Standard for Reduction of Soil Loss is necessary because other best management practices (BMPs) are available and have varying degrees of effectiveness.

Sojka and Lentz (1996) summarized several advantages of PAMs over other erosion control BMPs: (1) PAM can be applied using irrigation equipment and can be effective for controlling erosion over large areas, as demonstrated in eastern Washington and Idaho; (2) PAM is very effective on fine silt/clay soils; (3) preliminary research conducted in

Kansas and California has indicated that PAM is effective at abating wind erosion; (4) PAM enhances precipitation of fine silts and clay particles, providing water quantity benefits; (5) PAM increases soil infiltration capacity that reduces runoff volumes; and (6) high benefit to cost ratio.

The types of PAM used for erosion control should have an approximate molecular weight of 12-l 5 Mg/mole, with an 8-35% negative charge density, and contain no greater than 0.05% Acrylamide monomer (Sojka and Lentz 1996).

A recent study done by King et al. (1996) focused on comparing the uses of polyacrylamides and straw mulch on dry bean yields. It was shown that the sediment loss was reduced for both straw mulch and the PAM treatment.

In three years of studies in construction sites using PAM for controlling soil loss, PAM has provided a 60-97% reduction in runoff-sediment (Roa et al. 1997).

Method

Five treatments were applied to soil test plots: (1) No PAM-mix application to dry soil [control], (2) PAM-mix in solution applied to dry soil, (3) Dry PAM-mix application to dry soil, (4) PAM-mix in solution with mulch/seeding applied to dry soil, and (5) PAM-mix in solution applied to moist soil. Three replications of each treatment were performed using a randomized block design on 1 m x 1 m non-vegetated plots in the Middleton Hills Development, Middleton, WI. The soil was a Dodge silt loam. The average slope of the test site was 10%.

Plot preparations included large boulder, cobble, and excess debris removal. The surface was raked prior to testing. Soil moisture prior to testing was about 9%.

The PAM-mix is a high molecular weight anionic granular polymer. The PAM-mix (2.25 g of PAM-mix added to 5 liters of water) was applied at a rate of 22.5 kg/ha, to the appropriate plots using a garden sprinkler. For the dry PAM-mix application, 2.25 grams of the PAM-mix was applied using a sifter. For the PAM-mix applied to moist soil treatment, the soil was pre-moistened by a 6.4 cm rainfall six hours before testing.

The sprinkler infiltrometer (Bubenzer and Patterson, 1982) was used to collect data for this study. A rainfall simulator was used that produces 6.4 cm per hour. Actual rainfall depths were recorded using eight rain gauges for each replication. Runoff from each plot was collected into a tank where the depth of the water was recorded at approximately 2-minute intervals during each test. The average trial time was 40-50 minutes or until the runoff collection tankwasfilled.

Runoff samples were extracted at approximately 1 O-minute intervals by diverting runoff into a collection container during each replication to determine sediment yield. A representative sample was also taken at the end of each replication from the tank. The samples were dried at 11 0^{o}C for 24 hours and weighed to determine an average sediment load for each trial.

Results and Discussion

Mean sediment yield, infiltration, and runoff depth for the three replications and the controls are presented in Tables 1, 2, 3 and 4. For Replication 1, the PAM-mix solution was prepared the evening before field testing. It was noted that the viscosity of the solution decreased throughout the day. This change may have been due to UV light, reaction with the mix, and/or oxidative and photolytic interaction. Thereafter, the solution was prepared immediately before the rainfall simulation. After analyzing the results, a lower viscosity of the PAM-mix solution was determined to be less effective in controlling sediment yield. This difference is presented in Table 4. Future recommendationsforcommercial applications may need to take into account the time of preparation of the solution and handling before application.

During the first replication of testing, the largest sediment reduction occurred when PAM-mix in solution was applied to moist soil. The control yielded 184.4 grams per square meter and the PAM-mix in solution applied to moist soil yielded 36.4 grams per square meter resulting in a reduction of 80% in sediment yield (Table 1). The sediment yield reduction for the dry PAM-mix application to dry soil and PAM-mix in solution with mulch/seedling applied to dry soil were

Table 1. Summary of rainfall, infiltration runoff, and sediment yield for Replication #1 .

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	5.64	1.70	4.01	184.4	100%	71%
Dry PAM-mix/Dry Soil	5.79	1.91	3.89	68.3	37%	67%
Solution PAM-mix/Dry Soil	5.64	1.60	4.11	103.7	56%	73%
Solution PAM-mix/Moist Soil	5.72	0.05	5.66	36.4	20%	99%
Solution PAM-mix/Mulch/Dry Soil	5.72	1.57	4.14	67.3	36%	72%

approximately 64%. The sediment yield for PAM-mix in solution applied to dry soil was reduced by 44% when compared to the control.

In Replications #2 and #3, the lowest sediment yield occurred for the treatment of PAM-mix in solution with mulch/seeding applied to dry soil. A sediment reduction of 97% and 89% occurred, respectively. A sediment reduction for the treatment of PAM-mix in solution applied to dry soil was 87% and 57% respectively (Table 2 and 3).

Table 2. Summary of rainfall, infiltration runoff, and sediment yield for Replication # 2.

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	4.57	0.51	4.06	377.67	100%	88%
Dry PAM-mix/Dry Soil	5.72	1.57	4.14	178.36	47%	73%
Solution PAM-mix/Dry Soil	4.72	0.61	4.11	48.77	13%	87%
Solution PAM-mix/Moist Soil	4.14	0.13	4.01	242.4	64%	97%
Solution PAM-mix/Mulch/Dry Soil	4.55	0.38	4.17	12.04	3%	92%

Table 3. Summary of rainfall, infiltration runoff, and sediment yield for Replication # 3.

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	5.05	1.12	3.94	231.34	100%	78%
Dry PAM-mix/Dry Soil	5.38	1.96	3.43	43.29	19%	64%
Solution PAM-mix/Dry Soil	4.50	0.61	3.89	98.59	43%	86%
Solution PAM-mix/Moist Soil	4.42	0.28	4.14	47.65	21%	94%
Solution PAM-mix/Mulch/Dry Soil	4.39	0.38	4.01	26.58	11%	92%

When Replication #1 is excluded from the results, the average sediment reduction for PAM-mix in solution with mulch/seeding applied to dry soil increased from 87% to 94% (Table 4). The sediment reduction for PAM-mix in solution applied to dry soil was 76%. For dry PAM-mix applied to dry soil, the sediment reduction was 17%, and the sediment reduction of PAM-mix in solution applied to moist soil was 77%.

Conclusion

Our results show that, regardless of the application method, PAM-mix was effective in reducing sediment yield in the test plots. The most effective method of soil treatment throughout this study in reducing sediment yield is PAM-mix in solution with mulch/seeding applied to dry soil. The ease of application, low maintenance, and relatively low cost associated with PAM-mix makes it a practical solution to costly existing methods being implemented. The evidence from the field application in this study reflects that PAM-mix is a tool to reduce soil loss on bare soil until vegetation cover is established.

Table 4. Average summary of rainfall, infiltration runoff, and sediment yield for Replications 1, 2, and 3 and Replications 2 and 3, excluding Replication 1.

Treatment	Runoff (cm)	Sediment (gm)	Soil Loss % Replication 1, 2, and 3	Sediment (Gm) Excluding Replication 1	Soil Loss % Replication 2 And 3	% of Rainfall
Control	4.01	264.51	100%	304.51	100%	79%
Dry PAM-mix/Dry Soil	3.81	96.65	37%	110.83	36%	66%
Solution PAM-mix/Dry Soil	4.04	83.71	32%	73.68	24%	81%
Solution PAM-mix/Moist Soil	4.60	108.82	41%	145.03	48%	97%
Solution PAM-mix/Mulch/Dry Soil	4.11	35.32	13%	19.31	6%	84%

The primary factor that must be considered in future studies is the time of polymer solution preparation and application. It was noted that the optimal application procedure is to prepare the solution immediately prior to application. This procedure is necessary in order to limit the amount of degradation and maximize the performance of the PAM-mix.

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Construction Site Planning and Management Tools for Water Quality Protection

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California is seemingly a developer's paradise. Population is on the rise, the economy is good, and there is little or no rain to interfere with construction for nearly eight months of the year. To top off these benefits, the California Regional Water Quality Control Board, San Francisco Bay Region (Regional Board) has a comprehensive Construction Site Planning and Management Program (Program). It is based on the integration of a strong regulatory and enforcement posture, an outreach and education strategy, and technical assistance. The keys to the success of the program are the balance of actions among these elements and implementation tools for actions within them.

Background

The Regional Board is the state agency in California responsible for protection of water quality and enforcement of water pollution control regulations, including National Pollutant Discharge Elimination System (NPDES) permits. The California Water Code provides the Regional Board with strong enforcement authority. This authority ranges from a notice to comply, to a notice of violation, to enforcement orders, to monetary penalties. Penalties can be as high as $10,000 per day of violation or $10 for each gallon of waste discharged. The Regional Board may also suspend part of a penalty in exchange for an environmentally beneficial project.

In the San Francisco Bay Region, the Regional Board is responsible for enforcement of a general NPDES permit for stormwater discharges from construction sites of five acres or greater. The general permit requires implementation of an effective Stormwater Pollution Prevention Plan (SWPPP) that includes best management practices (BMPs) for erosion and sediment prevention and control and management of equipment, materials, and wastes. The Regional Board is also responsible for enforcement of NPDES permits for municipal stormwater discharges that have been issued to all municipalities (regardless of population) in the urban areas of the region. These permits include requirements to control discharges from construction sites (regardless of size). There is an inherent overlap of Regional Board and municipality authority over construction of five acres or greater. The Regional Board's Program recognizes and takes advantage of this overlap of authority.

Inspections

The Regional Board initiated an aggressive construction site inspection and enforcement effort in 1997. This resulted in discovery of significant water quality problems associated with sediment discharges caused by minimal or token erosion and sedimentation control actions. Some of the most common observations were:

- No permit.
- SWPPP not developed, not implemented, or deficient, especially in terms of timing.
- Mass grading allowed to continue throughout winter months until rain and muddy conditions make further work impossible.
- Mass grading continues past the time when grasses will grow and germinate; first rains simply carry seed/mulch away with eroded soil.
- No erosion control measures; reliance solely on sediment basins.
- Sediment basins are frequently undersized, improperly designed, and not maintained.

- Site not monitored to assess BMP effectiveness.
- SWPPP not updated to reflect changes in site conditions.
- Hillsides stabilized with hydroseed, but no mulch (resulting in rains carrying seed material away with eroded soils).
- Control measures driven by "tokenism" with control measures intended to demonstrate good intentions rather than real effectiveness.
- Willingness to risk fines in order to maximize work during winter (rainy season) months.
- Local agencies, specifically planners and engineers with plan-approval authority, often unaware of "best" management practices.
- Sites approved by local authorities for mass grading during rainy season.
- Local authorities review and approve erosion control plans but do not inspect sites.

Enforcement Actions

Several types of enforcement actions evolved from these findings. The first consisted of the development and issuance of a "Notice to Comply" (Figure 1). Often (25 - 35 % of the time) operators at a site are unaware of their requirements or appropriate BMPs. The Notice to Comply is essentially a "fix-it" ticket that results in no further enforcement action if corrective action is implemented. Regional Board inspectors are authorized to issue Notices to Comply in the field, and use of this simple enforcement tool has proven to be an effective mechanism to gain timely corrective action at construction sites.

Other enforcement tools are used in circumstances where the severity of the problem warrants more intensive enforcement action. These include, in terms of progressive severity: a Notice of Violation, a Cleanup and Abatement Order, and a Cease and Desist Order. Violations of any of these actions typically lead to more aggressive enforcement action. The most aggressive enforcement action is imposition of administrative civil liability (monetary penalties).

During the 1997/98 rainy season the Regional Board imposed over $1 million in penalties, ranging from $10,000 to $230,000. A major consideration in determining penalty amounts is ensuring that it does not pay to pollute. Due to the economic and time pressures associated with many development projects, minor penalties may simply constitute a cost of doing business. The Regional Board has clearly stated its intolerance to this circumstance and intends to severely penalize repeat offenders. Clearly, such penalties not only get the attention of the violator, but the building industry as a whole. Substantive penalties have also provided opportunities to fund environmental education projects in lieu of direct payment of penalties. The Regional Board has favorably accepted development of technical assistance tools as appropriate mitigation projects.

Education and Outreach

The Regional Board recognizes that regulation without education is ineffective. Consequently, its program includes extensive outreach efforts. These include:

- Mass mailing to construction projects of more than five acres and projects permitted for winter grading summarizing requirements and findings on inadequate performance
- Meeting with development community and local agencies prior to the rainy season (August through September) to better communicate concerns and requirements and to establish a dialogue
- Providing detailed guidance and training for both developers and municipalities on their responsibilities and on effective control approaches

San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400, Oakland, CA 94612 /Phone (510) 622-2300 - FAX (510) 622-2460

NOTICE TO COMPLY

You are hereby notified that ______________________ (hereafter Discharger) has violated provisions of: ☐ Order No. ______________________
☐ NPDES Permit No. (if applicable) ______________________
☐ California Water Code Section ______________________
• I Other ______________________
Federal, State, and Local Agency Contacts:
____

I. FACILITY INFORMATION
Inspection Date: ____________ Time: ______ Prior Notification: ☐ Yes ☐ ☐ ☐ Unknown
Discharger Contact: ______________________ Title:- ______________________ Phone: (___) ______________
Site Name & Location: ______________________ County: ______________
Headquarters/Owner Name & Address : ______________________
____

II. NON-COMPLIANCE INFORMATION

Nature of Violation :	Recommendation to Correct :	Time to Comply (Not to exceed 30 days)

III. SIGNATURE SECTION

I acknowledge receipt of this Notice (must be owner, operator, or duly designated representative of facility):
RECIPIENT NAME (print): ______________________ TITLE: ______________________
SIGNATURE: ______________________ DATE: ______________________
STAFF NAME: ______________________ PHONE: (-) ______________________
SIGNATURE: ______________________ DATE: ______________________

IV. CERTIFICATION OF COMPLIANCE

Sign and return by mail or fax within 5 working **days** of achieving compliance

I certify under penalty of perjury that the above violation(s) have been corrected.
I am aware that there are significant penalties for submitting false information.

Recipient Signature: ______________________ Date: ____________
Print Name: ______________________ Title: ____________

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Receipt Date: / /
Reviewed by:
Date:

Acceptable:
☐ ☐
☐ Yes
Recommendation:

Figure 1. Notice to Comply

The objectives of these outreach efforts are:

- Commitment from the construction industry to include erosion control in their planning, scheduling, and (most importantly) project implementation

- Commitment from municipalities to play a greater role in SWPPP review and implementation, including training inspectors so that builders, municipal staff, and Regional Board staff are all on the same page - thereby allowing for consistent regulation of construction activities by applying a uniform standard.

In response, the building industry and municipalities have collaborated with the Regional Board on the production of training workshops on construction site planning and management for both building industry and municipal staffs. The workshops provide a review of regulations and responsibilities including:

- State responsibilities
- Permits for work in or near streams
- Local agency responsibilities
- Plan approval authority and requirements
- On-Site responsibilities (plans, permits, inspections)
- Inspector responsibilities
- Enforcement
- Field inspection coordination (i.e., state agency/municipality)

The workshops also include training on BMPs for erosion and sediment control (principles, tools, corrective measures, inspections, monitoring, reporting), non-stormwater discharge prevention and management, and a field trip to an active construction site where vendors demonstrate both proper and improper installation practices.

Production of the workshops has been funded in part through mitigations associated with administrative civil liability fines. Similarly, penalty mitigation funds have been used to develop education tools including:

- An 18 minute training video entitled “Hold on to Your Dirt: Preventing Erosion from Construction Projects” which provides information on BMPs for grading projects and for stabilizing disturbed land

- An 18 minute training video entitled “Keep it Clean: Preventing Pollution from Construction Projects,” which provides information on BMPs to prevent water pollution from non-stormwater discharges from activities such as painting, stucco, concrete washout facilities and saw cutting

- A booklet of “Guidelines for Preparing a Storm Water Pollution Prevention Plan”

Erosion and Sediment Control Field Manual

The centerpiece of the Regional Board’s Program is an *Erosion and Sediment Control Field Manual* (also developed with penalty mitigation funds). The *Field Manual* was produced in response to a common complaint by “field” personnel that there is a need for information on cost-effective and proven BMPs, and that existing references were too technical and difficult to read. The *Field Manual* contains concise descriptions of BMPs for erosion and sediment control and site management (Table 1). Overviews of regulatory requirements and inspection and monitoring responsibilities are also provided.

Table 1. Erosion and Sediment Control Field Manual BMPs

Erosion and Sediment Control Field Manual BMPs	
Erosion and Sediment Control Practices	
• Scheduling • Preservation of Existing Vegetation • Slope Grading • Temporary Seeding and Mulching • Permanent Seeding and Mulching • Hydromulching – Hydroseeding • Dust Control • Erosion Control Blankets and Geotextiles • Fiber Rolls • Temporary Stream Crossing • Stabilized Construction Entrance • Entrance/Exit Tire Wash	• Outlet Protection – Energy Dissipation • Check Dams • Silt Fencing • Temporary Straw Bale Dike • Sand/Gravel Bag Barrier or Rock Filter • Storm Drain Inlet Protection • Catch Basin Inlet Filters • Sediment Basin • Sediment Traps • Dewatering: sediments/toxic pollutants • Secondary Filtration
General Site and Materials Management Practices	
• Water Conservation Practices • Solid and Demolition Waste Management • Hazardous Waste Management • Spill Prevention and Control • Vehicle and Equipment Service • Material Delivery, Handling, and Storage • Paints and Liquid Materials	• Handling and Disposal of Concrete and Cement • Pavement Construction Management • Contaminated Soil and Water Management • Sanitary/Septic Waste Management • Landscaping Management

BMPs are described in a user-friendly format that features full-color graphics, including do and don't illustrations (Figure 2). Each BMP description includes its purpose, application, limitations, practices, inspection, and maintenance. There is a section on Corrective Measures that discusses what can go wrong and common installation problems. This latter section is essentially a troubleshooting guide that contains a table of common problems and corresponding corrective measures. Overviews of regulatory requirements and inspection and monitoring responsibilities are also provided. The *Field Manuals* waterproof 9" x 9" binder and coated pages make it ideal for use in the field. As such, it provides the essential connection between the enforcement, outreach, and technical assistance components of the Regional Board's Program.

Overlap of State and Municipal Authorities

The Regional Board's Program provides a clear demonstration of how the Storm Water Phase II Program's construction requirements may be implemented. The Phase II rule allows states to recognize compliance with municipal program construction requirements as equivalent to compliance with a state-issued NPDES permit for construction, if it can be demonstrated that the municipal program requirements are equivalent. In such situations, a construction site deemed in compliance with a municipality's requirements would be deemed in compliance with the state-issued NPDES permit. The key is demonstration that the municipal program qualifies as equivalent.

In the San Francisco Bay area, as previously noted, the Regional Board has issued NPDES permits for municipal stormwater discharges that include requirements to control discharges from construction sites. In essence, there is an overlap of Regional Board and municipal authority where municipalities are in compliance with their permit requirements.

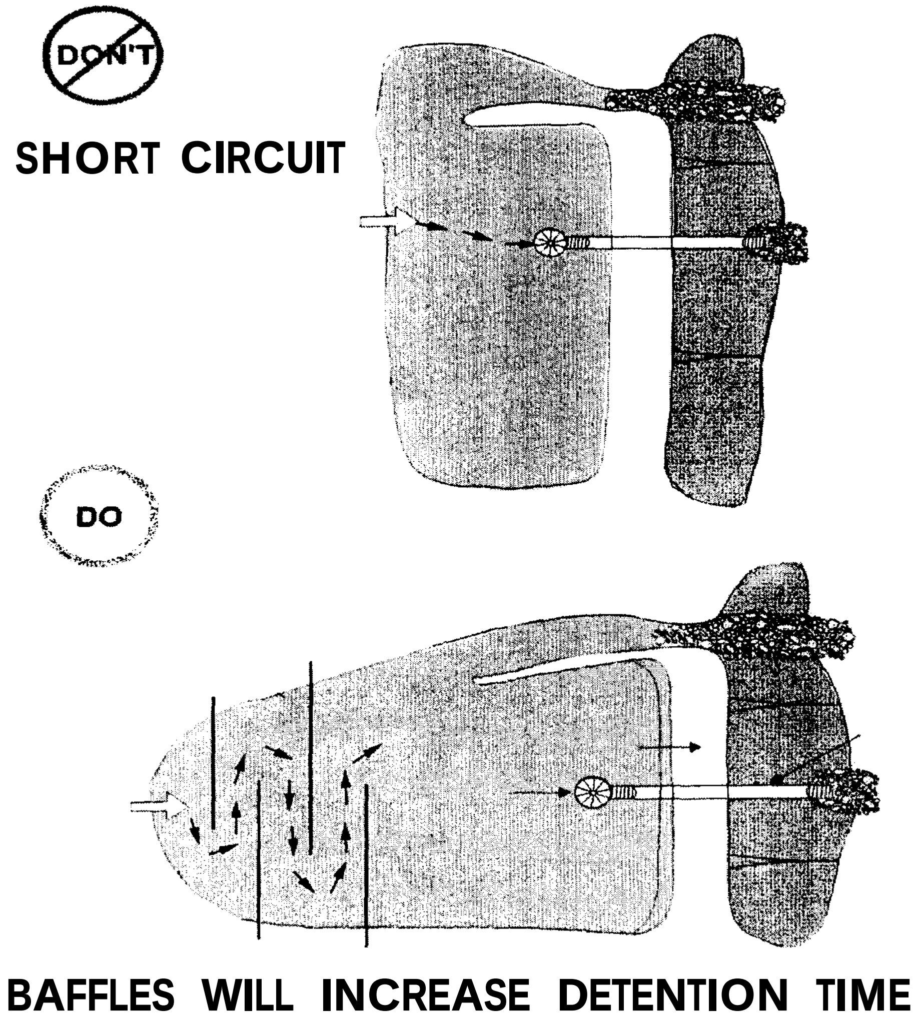

Figure 2. Sediment Basin Design.

Unfortunately, what may seem equivalent on paper may not be equivalent in practice. The case in point is that the Regional Board's inspection program noted above identified many construction sites out of compliance with their construction NPDES permits. Consequently, these same construction sites would be deemed in non-compliance with municipal requirements, In addition, the same inspection findings can be applied to the municipality. Since the municipality's NPDES permit requires it to control discharges from construction sites, construction site non-compliance means the municipality is not in compliance with its NPDES permit. In these circumstances, the Regional Board may (and has) taken enforcement action against both the construction site and the municipality.

To date, the primary enforcement tool used for the municipalities has been Notice to Comply. The Notice to Comply requires the municipality to report on the failure of its construction control program and to implement timely corrective actions. Most municipalities have been very responsive to this "wake-up-call," and have made improvements to demonstrate the desired "equivalency." The net result is a negative turning into a positive. The Regional Board's Program, with its balance between enforcement and education, has provided a *de facto* mechanism for recognizing municipal program equivalency allowed by the Phase II rule. By its design and implementation, the program essentially requires municipalities to demonstrate such equivalency. Consequently, the Regional Board will significantly reduce or eliminate its inspections in municipalities where Regional Board inspections find construction sites in compliance, thus providing incentive and reward to both the building industry and municipalities.

Lessons Learned

Lessons learned in the development and implementation of the Regional Board's Program are summarized in the following points:

- The only effective means of controlling erosion is erosion prevention, which requires careful planning and adherence to seasonal time-lines. Sediment capture should be used only as a secondary or back-up plan.
- Regulation without education is ineffective. Often, noncompliance is due to lack of awareness of the regulatory requirements and cost-effective, proven BMPs.
- Education without enforcement is impotent. Despite good intentions, the building industry is constantly trying to maximize its investment dollars, and environmentally sound BMPs are often superseded by time pressures to complete a project.
- Enforcement actions must be severe enough that they cannot be accepted as a cost of doing business.
- The balance between regulation and education is dependent on readily available technical assistance and implementation tools.
- Outreach and technical assistance needs to be directed to the right audiences. Workshop agendas and attendance were initially misdirected toward planners and local decision makers. Key attendees are municipal staff who actually review SWPPP plans and perform on-site inspections and building industry staff who are onsite. Evaluations revealed attendees wanted more technical information on installation and less time spent on municipal general plan/environmental plug. Audiences are especially responsive to builders discussing their experiences in implementing BMPs.
- Both the building industry and municipalities have historically short shrifted training. Workshop attendees expressed relief that practicable training is finally available - especially information on vendors, cost comparisons, and practical BMPs. The building industry and municipalities now realize costs of training are minimal relative to the benefit.

Conclusions

The bottom line is that environmental regulators, municipalities, and the building industry have different priorities that must be reconciled. Regulators seek no adverse impacts to waters. Municipalities seek economic growth. Builders want unfettered development. In the case of construction-related erosion, the means to each end is the same...effective erosion and sediment control. A little more work on the part of each party involved has proven that their different priorities are attainable and even harmonious.

Since the Regional Board made enforcement a top priority and began a collaborative effort with the building industry and municipalities to provide cost-effective outreach and training, construction site compliance with NPDES permit requirements has risen from 20% three years ago to greater than 90% today. Municipal compliance has risen similarly.

Regulating Sedimentation and Erosion Control into Streams: What Really Works and Why

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Abstract

The overall objective of this project was to determine the effectiveness of different environmental policies, regulations, and incentives in reducing the ecological risks and consequences of sedimentation to streams. We were trying to learn which sets of regulations, enforcement strategies, and landscapes result in effective protection of stream communities from degradation, resulting from erosion and sedimentation from construction sites. By connecting erosion control efforts to environmental impacts, our aim was to create more effective management strategies that ultimately provide environmentally sustainable social and economic development in our watersheds.

We chose four replicate construction sites in each of three regulatory jurisdictions that varied in stringency of regulations and enforcement activities. At each site, we conducted instream assessments of water quality and biomonitoring of macroinvettebrates and fishes to determine the success of the regulators in protecting stream ecosystem health. We combined these results with evaluations of the regulatory environment to link the policies and management styles of the regulators to the effectiveness of protection of the streams. While all construction sites did some damage to the steams, we found that enforcement style and frequency of inspections were far more important than the nature of the regulations in preventing sediment pollution of streams.

Keywords: Development, enforcement, rivers, sedimentation, streams, regulations, regulatory effectiveness.

Introduction

A critical problem in American rivers and streams is sedimentation. Sedimentation degrades water quality, alters habitat for fish and macroinvettebrates, limits ecosystem functions and services, and reduces the aesthetic and economic value of rivers and streams. Many regulations and policy incentives have been devised to control sediment pollution of our rivers and streams. Yet there has rarely been an attempt to reconnect the policies with the ecology of the rivers. That was the goal of this research. This work integrates the regulatory environment, sediment ordinances, and policies with resultant ecological impacts of sedimentation on rivers and streams. The question the ressearch sought to answer was "What combinations of policies, regulations and on-site interactions between regulators and developers really work to enhance stream biota and stream ecosystem health?"

Research goals were accomplished by comparing similar streams in different regulatory jurisdictions (a comparative watershed approach). We tested the effectiveness of different intensities of sediment control regulations and enforcement. We used the streams to tell us what matters ecologically. The selected political jurisdictions differed in the stringency of their erosion and sediment control requirements and the nature and intensity of enforcement of the regulations. We chose 17 construction sites along streams in three different jurisdictions. We interviewed the regulators and developers at each site and we studied the regulations and the attitudes of the regulators and developers. At each site, we sampled the streams being impacted. Some projects are still unfinished. Therefore, we will present only the results of the 'before construction' and 'during construction' samplings.

We asked "Which erosion and sediment control regulations really work and why?" We have analyzed the erosion and sedimentation control regulations and compared them among the respective jurisdictions. Then we surveyed the attitudes and enforcement activities at all levels within each jurisdiction. This paper will briefly outline our findings and focus on what can be done to minimize sedimentation into streams from construction sites.

Methods

Site Selection

We selected three regulatory jurisdictions so they would vary across a range of two critical variables: (1) stringency of regulations (how strict and how rigorous the rules are) and (2) stringency of enforcement (i.e. frequency of inspections, severity of punishment of violations). A summary of some of the salient characteristics of the three regulatory jurisdictions is given in Table 1. Construction sites were selected from the array of applications for grading permits filed with the erosion and sediment control offices in each jurisdiction. The biggest constraint in locating study sites was the availability of construction sites on streams with riffle zones, One jurisdiction (District IV) extends eastward into the coastal plain as does Eastern Wake County. Therefore, many otherwise promising sites, which had sandy bottomed, slow flowing streams, were eliminated from our study. To be selected for this study, the construction sites had to have certain critical characteristics. For example, streams had to be within 100m of the site. There also had be a significant slope from the construction site down to the stream, so that if erosion occurred it would impact the stream. These factors made site selection extremely difficult. In this paper, we will discuss only the impact of large construction sites (>100 acres disturbed). We have located and sampled ten large sites.

Table 1. Selected Characteristics of Erosion and Sediment Control Jurisdictions Used for this Project

	Minimum Disturbed Area Requiring Erosion Plan	# Field Staff	Total Area (Miles')	# Active Projects	Site/Staff Ratio
Orange County	0.5 Acres	3	400	-100	33.3
Wake County	1 .O Acres	4	858	-400	100
District 4' (16 Counties)	1 .0 Acres	4	8,116	-1000	250

* District 4, of the NC Division of Land Quality oversees all construction projects in all 16 counties without a Local Erosion and Sediment Control Program. It covers all governmental construction in the District 4 area, including Orange and Wake Counties. So, a single stream can have adjacent construction sites along the banks, one supervised by District 4 and the other by the Local Program.

Stream Sampling Procedures and Variables Sampled

We monitored at least three replicate sites per jurisdiction for the large construction sites. We sampled before, during, and after construction. We cannot control the timing of the construction projects, and since sampling must follow a rain of >1/2" in 24 hours (i.e., a rain with the potential to produce erosion and sedimentation), our sampling was dependent on the weather and the contractors. This means that the time between the before, during, and after sampling is highly variable. Since upstream and downstream controls were sampled on the same day as the "at the site" samples, this did not cause a significant analytical problem.

We sampled three sites on each stream, including >1 00m upstream, at the site, and >1 00m downstream. We took two replicate Surber samples for macrobenthos, identified to species whenever keys permitted, including chironomids. Chironomids are essential because they often constitute >90% of the individuals sampled, especially in the impacted reaches. The number of samples is small since our objective was not to analyze any one stream in detail, but to treat streams as replicates. In the overall analyses, multiple samples per site are pseudoreplicates. The mean of the replicate Surber samples was used in the analyses. We electroshocked for fish along one 50m reach of riffles and pools. We collected basic water chemistry data. Water quality parameters included D.O., turbidity, conductivity, Total N, NH,+, NO_3^{-1}, Total PO,-‘, SRP, pH, and temperature. We also studied leaf litter decomposition rates. Five g leafpacks of *Cornus florida* (dogwood) leaves were incubated for two weeks *in* situ at all three sites in the “during construction” period to assess the critical ecosystem process of litter decomposition.

Environmental Policy Analysis

Surveys and semi-structured interviews were used to investigate both the regulatory agencies and developers. The surveys focused on the capacityof the agency, the external commitmentthat the agency receives, as well as the internal commitment toward the environment, and the *control* measures that are used. The surveys and interviews achieved a 100% response and participation rate. Although it has been harder to get their cooperation, we have nearly completed data collection from developers. The survey data is being augmented with documentary data from the sediment and erosion control offices in each of the counties.

The evaluation of implementation focused on (1) the extent to which developers comply with sediment and erosion control regulations and (2) the way that regulatory and organizational factors interact to shape compliance behaviors. The examination of outcomes combines social science and biological data to examine associations among regulatory styles, agency activities, and stringency of policy enforcement. We further analyzed how variations in sediment and erosion control enforcement are related to the ecological outcomes (including biological, chemical, and physical factors) in the impacted streams.

Hypotheses

Hypothesis 1. Greatest degradation will be evidenced at the construction sites, compared to upstream controls, with moderate to complete recovery downstream.

Hypothesis 2. Tighter enforcement of erosion and sediment control laws will result in less damage to streams.

Hypothesis 3. Stronger erosion and sediment control regulations will result in less damage to streams.

Results

Nearly all biotic and environmental variables measured tell the same story. Figure 1 shows the changes in the EPT Index for the during construction sampling. That is the species richness of the Ephemeroptera (the mayflies), Plecoptera (the stoneflies), and Trichoptera (the caddisflies). The tally of EPT taxa (i.e., EPT Richness or the EPT Index) is a well-established and universally accepted measure of stream health. These groups of aquatic insects are particularly sensitive to (and highly intolerant of) high temperature, low oxygen, toxic substances, a wide range of pollutants, and burial by sedimentation. An abundance of EPT species and individuals and high EPT diversity are clear indicators of good stream health. Reductions in EPT values demonstrate degradation of stream conditions.

EPT richness follows a pattern. The differences between jurisdictions are clear. The greatest decline in EPT values from upstream to at-the-site occurs in District IV. The EPT Index in Orange County changes little at any site. Wake County actually shows some enhancement of the EPT richness as you go from upstream to at-the-site. We sampled many other variables but the results parallel the EPT richness.

A short summary of the enforcement activities and attitudes of the regulators in the various jurisdictions is found in Table 2. These data show that these agencies differ in these aspects. Orange County had the strictest enforcement, penalizing nearly 25% of all construction projects, while Wake penalized -22% and District IV penalized only ~ 4.5% of the projects they inspected. Orange County is most likely to use stop-work orders to halt construction due to sedimentation violations, while District IV relies on fines. District IV is perceived as being so understaffed that it is unable to make sufficient inspections. Consequently, some contractors do not feel obliged to follow their approved plans. Some contractors agree to a plan and then cut costs by not following the sediment controls. This laxity is detectable from the stream data (see Figure 1).

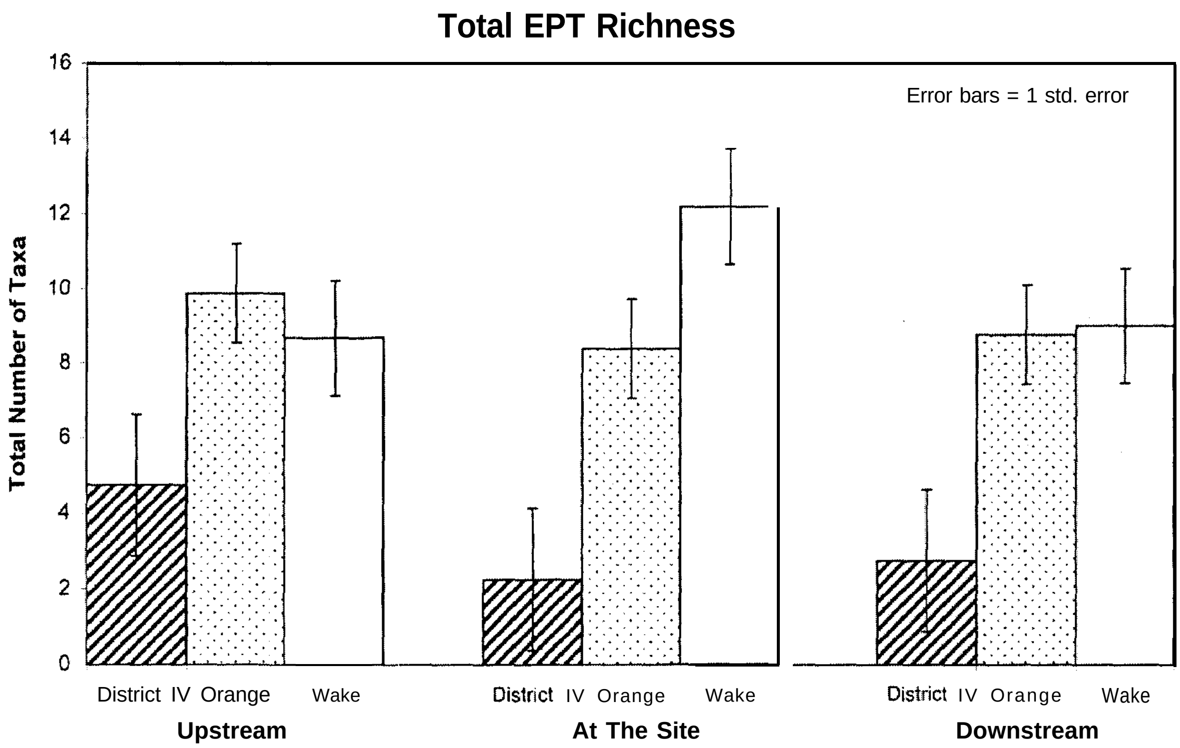

Figure 1. Total EPT Richness.

Table 2. Regulatory Environment

Agency/Variables	Orange County	NC District IV	Wake County
Enforcement Action	Very Strict	Average	Strict
Penalties enacted past year	24	44	88
Stringency of Penalties	High	Medium	Medium
Attitudes of Regulators			
Perception of official commitment	Supportive	Very Supportive	Indifferent
Percent of developers that regulators	8	40	10

Orange County and Wake County regulators generally think that developers will try to avoid complying with erosion and sediment control regulations. As the regulators' workload increases, their task becomes more difficult. This may result in regulators adopting a more forgiving attitude toward developers and less vigorous enforcement of the regulations. District IV regulators think that fully 40% of developers are trying to comply with the regulations.

Discussion

There is a clear link between the attitudes and enforcement activities of the regulators of erosion and sediment control ordinances and environmental outcomes in the streams near construction sites. If the regulations are completely effective, all sites should be similar to the upstream controls when the construction is completed and the site has been stabilized (i.e., revegetated). In our analysis, the degradation is clearly detectable in the benthic community data (see Figure 1). Benthic communities at the site are dramatically negatively impacted in District IV, unchanged in Orange County, and actually enhanced in Wake County. The effect is sometimes reduced downstream but the degradation persists downstream in District IV.

Wake County and District IV have identical regulations, while Orange County's regulations are more stringent. Comparison between the two jurisdictions with the same rules but different inspection and enforcement intensities will help us tease apart these factors. The stream data suggest that the laws, as written, are not particularly important. Wake County has the best environmental results while District IV has the worst stream degradation. Our analysis suggests that differences in laws and regulations have limited impact on the degree of degradation of stream biota.

The key factors seem to be the attitudes and enforcement behavior of the regulatory agencies. The frequency of on-site inspections is particularly important. In Orange County, every construction site is inspected every week. If it is a problem site, the inspectors may visit daily. In Wake County, the inspections are closer to every other week. In District IV, the goal is to visit every site once in the entire duration of the project. They also seek to respond to any citizen complaints within one week. In Orange County a complaint generates an inspection within one day. Another critical factor is topography. A very steep, erodible slope can undermine the best attempts at enforcement of erosion and sediment control regulations.

Our analysis suggests that differences in the nature and frequency of enforcement and inspections does matter. Developers tell us that a rigid, command and control approach to enforcement is less palatable to them than a flexible problem-solving cooperative approach. If the developers perceive that the regulators are really tying to help them keep sediment on site and out of the streams, they do a better job. Flexibility enters in as follows. If the sedimentation inspectors have enough time to analyze a sedimentation problem in detail, their suggestions will be better. Very often, the inspectors need the authority to implement solutions which are not exactly "by the book." When inspectors propose innovative solutions, which can really solve the problem, this encourages the developers to be more cooperative. More frequent inspections and a cooperative, flexible approach by regulators does ameliorate the stream damage among similar streams in different jurisdictions.

On the other hand, if the developers know that the regulators will in fact shut them down (with a stop-work order or a court injunction), it is easier for the regulators to get developers' attention. Fines are notoriously ineffective penalties in North Carolina. Presently the maximum fine is $500 per day. When developers are pouring millions of dollars into a project, this amount of fine is trivial. As one said, "It's just a cost of doing business." In essence, the effectiveness of erosion and sediment control depends more on enforcement than on how the regulations are written. Even with weak laws, the success of Wake County's Erosion and Sedimentation Control Program plainly depends on their on-site enforcement actions.

Recommendations

- Provide sufficient inspectors to visit each construction site at least weekly.
- Give inspectors the authority and knowledge to implement innovative solutions to erosion problems on a site-specific basis.
- Empower the inspectors to issue severe penalties (stop-work orders) in the case of sedimentation violations.
- Raise the maximum level of fines to a meaningful amount (we suggest $10,000 per day).
- Educate the development community to the damage that sedimentation does to stream communities.

Effectiveness in Erosion and Sediment Control: New Initiatives in Indianapolis

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Since the late 1960s, when the severity of pollution from sediment from construction sites was first documented, many states and municipalities have worked to develop effective programs for erosion and sediment control. These state and local programs were augmented in 1987, when Congress required in the Clean Water Act that operators of all construction sites over five acres prepare erosion and sediment control plans and obtain National Pollution Discharge Elimination Permits (NPDES). At that time, some states, such as Maryland and North Carolina, already had well-supported, comprehensive approaches that were developed largely in response to state law. Other states, including Indiana, have relatively new programs that were adopted only after the federal mandate. In general, these newer programs are not as comprehensive, and managers are still working to develop systematic and effective methods for implementation.

This paper describes a new initiative in Indianapolis, Indiana, to increase the effectiveness of erosion and sediment control programs. The paper describes a general framework for evaluating erosion and sediment control programs. Next, it describes an intergovernmental, "S.W.A.T." team approach to inspection that was used in Indianapolis in the summer of 1998. The paper summarizes the results of the inspections and concludes with a discussion of the implications for managers of erosion and sediment control programs.

Effectiveness in Erosion and Sediment Control Programs

Managers and analysts in Maryland and North Carolina have used a general framework for evaluating erosion and sediment control programs (Clevenger, n.d.; Departments of Civil Engineering and City and Regional Planning, 1990). The framework comprises five criteria, each of which must be satisfied for sediment pollution to be controlled effectively:

- Complete coverage
- Competent plans
- Careful installation
- Continual maintenance
- Consistent enforcement

Overall effectiveness requires that the coverage rate (the proportion of construction sites with controls) approach 100%. Operators of development sites must know of regulatory requirements and make efforts to comply. Second, erosion and sediment control plans must be competent. Best management practices (BMPs) incorporated into plans by engineers or technicians must be able, if constructed properly, to control erosion and sedimentation. Third, BMPs must be installed completely and correctly. Improper installation may result in failure and off-site sedimentation. Fourth, BMPs must be maintained for the duration of the construction process. Finally, consistently effective approaches to enforcement must be developed to ensure compliance with substantive criteria. If any one of these criteria is not met, the objectives of erosion and sediment control may not be achieved.

When new programs are developed, these criteria can be considered sequentially. That is, when building a new program, managers must first make sure that developers and builders are aware of regulatory requirements. Next, they must work to ensure that developer's engineers are preparing good plans. If developers are aware of requirements and are submitting good plans, attention can turn to installation and maintenance. Use of enforcement tools always is a last resort.

An Initiative in Indianapolis

Although the City of Indianapolis has a sediment control ordinance that predates federal requirements, erosion and sediment control programs in Indiana have largely been developed in response to a state regulation [Title 327-IAC 15-5 (Rule 5)], that was adopted in 1992 to comply with EPA regulations. Since the adoption of Rule 5, managers generally have seen improvements in efforts to comply. Most developers and builders are now aware of requirements, and coverage is approaching 100%. With respect to plan review, the Division of Permits in the Department of Capital Asset Management (DCAM) is responsible for plan review pursuant to the city's ordinance, while, under a memorandum of understanding with the Indiana Department of Environmental Management (IDEM) and the Department of Natural Resources (IDNR), the Marion County Soil and Water Conservation District (District) is responsible for plan review pursuant to Rule 5. MCSWCD reviewers estimate that the quality of plans is improving, but that as many as 60 to 70% of all plans still must be returned and revised before approval. Most plans are approved on the second iteration.

Although the review process now assures that competent plans are being prepared, installation often remains inadequate, BMPs often are not maintained, and resources for inspection and enforcement are limited. IDNR has only seven inspectors in the Division of Soil Conservation for all 92 counties and 550 municipalities. IDNR inspectors generally work individually within regions, inspecting sites sequentially and in response to complaints. District personnel lack enforcement authority and mainly visit sites in response to complaints. In Indianapolis, sediment control has been a low priority with DCAM, which has no inspectors trained in or assigned exclusively to enforcement of sediment control requirements.

Managers have struggled to find ways to overcome resource limitations and to increase the effectiveness of implementation. In 1998, IDNR and District staff conceived of a "S.W.A.T." team approach to inspection. In this approach, all IDNR inspectors and District staff together focused their efforts on all open construction sites in the county. The objective was to visit all sites in a brief time period, thereby increasing the visibility of the program. Managers believed that intensive scrutiny of the county, if only for a brief time, would result in greater efforts at compliance. One of the assumptions on which this approach was based was that there are both formal and informal networks among developers and builders and that this approach would stimulate discussion about compliance issues.

In Indianapolis, IDNR and District personnel completed a county-wide survey of construction sites on June 23 and 24, 1998 (Hayes and Matthieu 1998). DCAM staff was invited to participate. IDNR, District, and DCAM staff visited more than 300 construction sites. Of these sites, 177 were active and were evaluated for compliance with Rule 5. Construction had not yet begun at 23 of the sites, construction had been completed at 61 sites, and the remainder were not evaluated because they were inaccessible or because construction was just beginning. This summary is restricted to the sites under active construction. The results provide a good picture of the current status of implementation and the general level of effectiveness of erosion and sediment control requirements in Indianapolis.

Inspectors evaluated sites for compliance in nine categories using a standardized checklist developed by IDNR. Sites also were checked for obvious evidence of off-site sedimentation. The nine categories were: (1) proper installation of erosion and sediment control measures; (2) perimeter erosion control measures; (3) erosion and sediment control measures on individual building sites; (4) protection of storm-sewer inlets; (5) stabilization of disturbed areas, (6) proper stabilization of drainage channels; (7) stabilization of drainage outlets; (8) maintenance of existing erosion and sediment control measures; and (9) tracking or accumulation of sediment on roadways. These criteria generally can be grouped within the installation and maintenance stages of the evaluation framework outlined above, although most involve aspects of both installation and maintenance. The first seven criteria primarily concern installation of BMPs; only two, maintenance and tracking, primarily concern maintenance.

Inspectors rated each applicable criterion at each site on a scale of Satisfactory, Marginal, Unsatisfactory or not applicable (NA). Items in compliance with Rule 5 were rated S, items that were in danger of becoming out of compliance were rated M and items in violation of Rule 5 were rated U. Because all criteria were not applicable at all of the sites, the number of sites evaluated for with respect to each criterion varies.

Disturbing Results from Disturbed Sites

The results of the inspections are summarized in Figure 1 (Hayes and Matthieu 1998). Overall the results show that installation is inadequate and that maintenance is worse. Improvements in implementation clearly are needed. Discussion of each of the nine items reviewed follows.

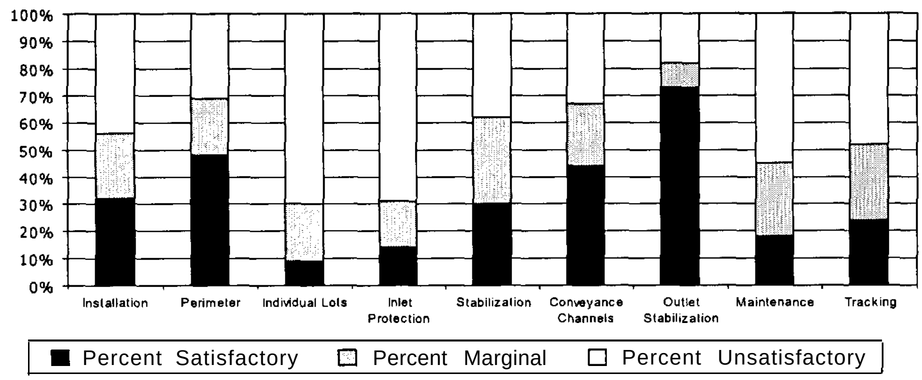

Figure 1. Rule 5 Compliance Summary-Percent of Applicable Sites.

Installation of Erosion Control Measures

Erosion control depends upon installation of appropriate control practices in given situations. Examples of these practices include silt-fence perimeter controls, sewer inlet and outlet protection devices, and the use of stone or mulch to stabilize slopes. Proper installation of these devices and practices helps reduce the risk of failure that may result in erosion and off-site sedimentation. Erosion and sediment control measures were installed correctly at only 32% of the active sites. Installation was marginal at 24% of the sites and had been done incorrectly at 44% of the sites. Proper installation was marked not applicable in cases where no erosion control practices were in use.

Perimeter Erosion Control Measures

Perimeter erosion control measures are designed to keep sediment from leaving a site directly at its perimeter through sheet or gully erosion. Perimeter erosion control devices/practices such as silt fence or buffer strips should be installed before land disturbance begins. The most effective and cost-efficient perimeter control practice is to leave existing vegetation in place, especially along waterways. Perimeter measures were installed and in compliance at 48% of the sites. Marginal conditions were found at 21% of the sites, and 31% of the sites were found to be out of compliance. Perimeter erosion control measures were not applicable at level or inward-sloping sites.

Individual Building Sites

Under Rule 5, erosion control is the responsibility of the site operator, either the developer or builder, throughout construction. At some sites, after the infrastructure has been installed and the lots have been sold to individual builders, the developer no longer has direct control over erosion and sediment control practices on those lots. Builders and contractors may or may not install and maintain erosion control practices. Erosion control on individual building sites is a serious problem in Marion County. Erosion and sediment control measures on individual building sites at developments were found to be adequate at only 9% of the active construction sites. Measures were in marginal condition at 21% of the sites, and 70% of the sites were found to be out of compliance. Most of these sites lacked proper construction entrances, storm-sewer protection, and perimeter protection. This category was not applicable for sites that had not yet begun construction of homes.

Storm-sewer Inlet Protection

Sediment entering storm-sewer inlets significantly reduces the capacity of retention/detention basins and drainage channels to store and convey stormwater away from flood prone areas effectively. If sediment is not removed prior to site closure, the specified volume and dimensions of retention/detention basins that were approved by the City can change. Inlet protection measures are especially important when sediment is tracked into or allowed to accumulate in roadways where it is conveyed directly to sewer inlets. Using measures such as seeding and silt fence adjacent to inlets will prevent sediment from clogging inlet protection devices and accumulating in the streets. Storm-sewer inlets were adequately protected from sediment at just 14% of the construction sites. Sewer inlets were marginally protected at 17% of the sites, and inlet protection measures were inadequate and not in compliance at 69% of the sites. Inlet protection was not applicable to sites that had not completed sewer installation.

Stabilization of Disturbed Areas

Stabilization of disturbed areas on construction sites may be the single most important practice for reducing erosion and off-site sedimentation. The best practice for achieving stabilization is to leave vegetation in place wherever possible. If soil must be disturbed, stabilization is relatively easily accomplished through temporary seeding or application of erosion control blanket. Rule 5 requires that disturbed areas that will be inactive be temporarily seeded. Stabilization by seeding results in higher perceived value by potential buyers, offering developers a financial incentive to vegetate land as soon as possible once the infrastructure is in place. Of active sites that were visited, 30% were in compliance with Rule 5 with respect to stabilization of disturbed areas, while 32% of the sites were marginal and 38% were not in compliance. This category of compliance was not applicable to sites that were being actively cleared or nearly completed at the time of the visit.

Drainage Channel Stabilization

Ditches and swales designed to convey storm water away from development to natural drainage ways or storm-sewers are subject to severe erosion and deterioration if not adequately protected. Erosion and damage to conveyance channels results in off-site sedimentation of waterways. This can be avoided by stabilizing the soil in conveyance channels immediately with permanent seeding of grasses, or with stone, mulch, or straw cover. Conveyance channel stabilization was satisfactory at 44% of the sites, Approximately 23% of the sites had marginally protected channels and 33% of the sites had channels in unsatisfactory conditions. Conveyance channel stabilization was not applicable at sites that did not have or require channels or at those that did not yet have them constructed.

Outlet Stabilization

Storm-sewer and drainage channel outlets from a site need to be properly stabilized to prevent erosion and sedimentation of the banks and waters they empty into. Outlet stabilization is best accomplished by protecting the soil around the outlet with stone riprap, geotextile fabric, or with well-established vegetation. Outlet stabilization was satisfactory at 73% of active sites. Outlets were in marginal conditions at 18% of the sites and unsatisfactory at 9%. This category was not applicable at sites that did not have outlets on the site or where infrastructure development was not yet completed.

Maintenance of Erosion Control Practices

Erosion control practices that have been installed properly must be maintained to be effective. In most cases, lack of maintenance results in the same effects as not employing erosion control practices at all. Examples of maintenance of erosion control practices include removing accumulated sediment from behind silt fence and reinforcing inlet protection after storms. Failure of erosion control practices allows sediment to leave construction sites via storm-sewers, drainage channels, roadways and sheet and gully erosion, An often-overlooked aspect of maintenance is removal of devices after work is completed. Maintenance of erosion control practices was satisfactory at only 18% of the sites. Maintenance was marginal at 27% of them, and there was little or no evidence of maintenance at 55% of the sites. Maintenance of erosion control measures was not applicable at sites that did not employ erosion or sediment control practices.

Sediment Tracking and Accumulation in Roadways

Soil and sediment in streets and roads are readily washed into sewers and drainage channels and can be a significant source of pollution. In addition, the sediment can be a traffic hazard with the potential for costly litigation against the local governments or developers. Sediment accumulated in roads is also unsightly and may discourage potential home buyers. Tracking and accumulation of soil in roads was kept to an acceptable level at 24% of the sites. Approximately 28% of the sites exhibited marginal compliance with the rule for keeping roads clear of sediment. Sites that were out of compliance with the rule made up 48% of this category. Large industrial sites where equipment was usually kept on site and residential sites that did not yet require extensive coming and going of vehicles were rated not applicable for sediment tracking.

Off-site Sedimentation

Sediment is the most abundant pollutant, by volume, in Indiana waters. Residential and commercial development sites are potential sources of high volume, sudden discharges of sediment that can cause problems for land owners down-stream of development. Besides the drainage and flooding problems caused by off-site sedimentation, sediment can obstruct and widen streams and erode stream banks. Sedimentation of the state's streams and rivers also causes habitat damage for many aquatic species. There were obvious signs of off-site sedimentation at 21% of the active sites. This figure is believed to be low, however, due to the large number of sites surveyed in a very short time. Only the most obvious cases were checked as displaying off-site sedimentation.

Observations and Implications: Priority-problem Solving

A number of observations that have important implications for managers of erosion and sediment control programs can be drawn from this inspection initiative. First, it is useful to consider the initiative in the more general framework for effectiveness in erosion control. Indiana regulations for erosion and sediment control first were adopted in 1992. Faced with implementation of a new regulation with few resources, IDEM, IDNR, and District staff first devoted efforts to education and ensuring complete coverage and competent planning. In late 1997 and early 1998, program managers determined that the plan review process was fairly well established and that additional effort needed to be devoted to installation and maintenance of BMPs. Because resource shortages preclude regular, periodic inspection, IDNR officials developed a S.W.A.T. team approach. Teams of state, district, and available municipal officials focused inspection efforts, visiting and inspecting as many sites as possible in a short time.

In Indianapolis, the results show that implementation generally is poor. Installation of erosion and sediment controls was unsatisfactory on 44% of all sites, and satisfactory on less than one-third. With the exception of outlet stabilization practices, which had been installed properly at nearly three-fourths of the sites, no practice was installed properly on more than half of the sites. Perimeter controls, a basic practice, were installed satisfactorily on fewer than half of the sites and they were unsatisfactory at almost one-third. Stabilization was satisfactory at less than one-third of the sites, inlet protection had been installed properly at less than 15% of the sites, and controls on individuals lots had been installed properly at just 9% of the sites where they were needed. It is clear that installation is deficient and that additional effort is needed to ensure that practices identified on plans are installed properly.

The inspections show that maintenance of erosion and sediment controls is even worse than installation. Inspectors determined that maintenance of controls was unsatisfactory on 55% of the sites and satisfactory on only 18%. Mud is being tracked on streets and washed into sewers and drainage channels on almost half the construction sites. Additional field work to ensure proper maintenance of BMPs is a critical need.

Although these results were disturbing, they were not unexpected. Program officials knew that implementation was inadequate and devised the S.W.A.T. team approach to provide a quick, comprehensive assessment of the status of implementation. Since the inspections, program managers have used the results as part of overall efforts to increase understanding of requirements for erosion and sediment control and to build commitment to the programs. City staff agreed to mail copies of inspection reports to all developers, and the district provided a summary of results to all city-county councilors.

The results provide information that program managers can use to establish priorities for problem solving and education. For example, installation of perimeter controls appears better than efforts to stabilize disturbed areas on site. Future inspections and educational efforts therefore can focus on the importance of stabilization. Similarly, since it appears that site operators are doing a fairly good job at stabilization of outlets, this requirement can be de-emphasized, and additional effort can be devoted to solving problems like installation of controls on individual lots that are not controlled by practices on the larger development site. More generally, as more people understand the different steps in the process of erosion and sediment control, implementation should become more effective.

The survey did not focus on discovering reasons behind compliance or non-compliance, but several inferences can be drawn from these data. First, the data and experience indicate that some developers are unaware of their obligation to control erosion and sedimentation and leave the permitting and erosion control planning to engineers and contractors. This can result in a lack of commitment to implementation. Second, some developers, engineers and contractors clearly do not yet understand the purpose and importance of implementing erosion and sediment control practices. Education is needed to increase their understanding and commitment. Third, some operators know the requirements of Rule 5, but do not take them seriously, ignoring the Erosion and Sediment Control Plan. For these individuals, enforcement action may be required. In addition, a general problem that was observed has to do with sequence of construction. All too often, land disturbance is beginning before erosion and sediment control measures are installed. More emphasis must be placed on installation of practices prior to earth disturbance, and site operators must learn to follow the sequence described on plans.

Given that resource shortages are likely to continue, problems in implementation are likely to continue and regulatory programs are likely to remain less effective than they could be. Steps that may be taken to increase effectiveness include making sure that the regulated community participates in on-site, pre-construction meetings that underscore the scope and importance of controls: increasing the visibility of IDNR and District staff and the frequency of their site visits; educating developers, engineers and contractors about erosion and sediment control practices and how to install and maintain them; and emphasizing the need for erosion and sediment control throughout the entire development process.

The S.W.A.T. team approach clearly does not solve the problems of a relatively new, understaffed erosion and sediment control program. But the approach is an effective way to obtain a significant amount of information in a short time, raise the visibility of erosion and sediment control programs, and help establish priorities for problem solving.

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Using Constructed Wetlands to Reduce **Nonpoint Source Pollution in Urban Areas**

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Abstract

Potential pollutants carried in stormwater runoff from urban surfaces are a major component of Nonpoint Source (NPS) pollution. NPS pollution is a leading cause of reduced water quality in US rivers and lakes, and there are major efforts underway to find innovative approaches to reducing NPS pollution from a wide range of sources, In urban areas, where much of the land has existing structures, a major challenge is to find ways to retrofit built sites to reduce NPS pollution associated with stormwater runoff. One component of this may be more widespread use of constructed wetlands that have value not only in terms of water quality improvement, but also in terms of urban ecology, aesthetics and education.

We have begun a long-term monitoring program of the performance of constructed wetlands in two settings: 1) On a commercial site where surface runoff is dominated by stormwater flow from parking lots and store roofs, and, 2) On a golf course that receives considerable surface flow from adjacent commercial, residential and highway areas. Monitoring includes both continuous measurements of flow, temperature, conductivity, pH and dissolved oxygen, and automated sample collection during storm events for more complete chemical analyses. Initial results suggest that the commercial site constructed wetland acts as an efficient trap during the spring and summer for suspended sediment and some dissolved matter. During the fall and winter dormant season trap efficiencies are much lower, and in some cases negative. The golf course site constructed wetlands also function as efficient traps during the summer, and plant growth in these wetlands has been helped considerably by the regular water supply provided by golf course irrigation. Both wetland systems also provide value in terms of improved aesthetics, their use by local educators, their diverse ecological assemblages, and the public relations benefits associated with visible efforts at improved environmental management.

Replacing portions of existing parking lots with carefully designed constructed wetlands, and adding constructed wetlands to urban recreational sites (such as golf courses and parks) should be viewed as one of several elements of an integrated approach for effective retrofitting urban areas to reduce NPS pollution from stormwater runoff.

Introduction

One of the major challenges facing urbanized areas is to find ways to improve environmental management in ways that do not involve major, costly impacts on existing infrastructure. Increasing recognition of the environmental impacts of built areas on parameters such as runoff amount and quality has increased regulatory and public pressure to develop and implement effective management practices. However, many of the best management approaches that can be integrated into the design of new developments cannot be implemented in existing built areas without prohibitive costs. Thus there is considerable interest in best management practices that can be used to retrofit urban areas for improved environmental performance.

Wetlands have the ability to store large amounts of water, reducing flooding of surrounding areas and in some cases recharging groundwater (Mitsch and Gosselink, 1993). In addition, wetlands are capable of improving runoff quality in many situations (Perry and Vanderklein, 1996) because they trap both solid and dissolved pollutants. Wetlands also can have considerable aesthetic benefits, and provide habitat for a wide range of plants and animals. Constructed wetlands are wetlands specifically designed and built for hydrologic and water quality management, as opposed to either natural wetlands or created wetlands. Created wetlands are designed and built to replace lost wetlands or to compensate for destruction of natural wetlands. Using constructed wetlands for water treatment attempts to take advantage of the benefits of wetlands without compromising natural wetland areas.

In urban areas there are unique challenges to be faced in proposing and designing constructed wetlands, Existing built areas rarely include extensive undeveloped space that can be converted to constructed wetlands. However, there are several opportunities that arise in many areas, including: 1) Making space by reducing the size of an existing parking lot; 2) Adding a constructed wetland to a redevelopment or urban renewal project; 3) Adding a constructed wetland to a park or green space; 4) Adding constructed wetlands to existing recreational facilities such as golf courses. A second major challenge in proposing constructed wetlands in built urban areas is to maintain adequate hydrology for long-term wetland survival. The extensive impervious surfaces of built areas generate large amounts of runoff during storm events, but this water is usually routed quickly away from the built area to prevent flooding. Because there is little opportunity for rainfall to infiltrate into the soil in urban areas (because most soil is covered by impervious surfaces), shallow groundwater flow is reduced. This means that wetlands in urban areas will receive far less between-storm water recharge from shallow groundwater than would be expected for a similar non-urban setting. In essence, wetlands in urban areas will experience a “flood and drought” hydrologic regime, which is poorly suited to an ecosystem that is based on extensive periods of wet conditions. One way around this problem is to look for locations where water is applied regularly to adjacent areas, in particular where extensive irrigation is used. Golf courses and lawns and gardens of major corporate complexes are potential sites where between storm irrigation might provide excess runoff and soil water drainage to adjacent constructed wetlands.

Given the potential use of constructed wetlands to improve water quality in built areas, it is important to evaluate how well wetlands function as pollutant traps in such settings. Such studies can be used to drive design improvements, and to evaluate the cost-effectiveness of using constructed wetland for NPS pollution control. Although there has been less work done in the area of stormwater constructed wetlands, in comparison to wetlands used as part of a wastewater treatment system (e.g. Hicks and Stober, 1989), limited results so far suggest that wetlands can be effective in treating stormwaterfor nonpoint source (NPS) pollution (Mitsch and Gosselink, 1993; Witthar, 1993; Livingston, 1989). Few data sets are available because of poorfollow-up of constructed wetland performancethrough appropriate monitoring programs (Perry and Vanderklein, 1996). However, available studies to date and theoretical reasoning suggest that NPS pollution control is enhanced by maximizing the distance between the wetland’s inlet and outlet, including deep and shallow sections in the wetland, selecting vegetation on the basis of climate and water quality and supply conditions, maximizing the ratio of treatment area to base flow, and minimizing the slope along which the water travels (Horner, *et al.*, 1994; Witthar, 1993). The idea in such a design is to model the constructed wetland after a natural wetland, which not only has the ability to slow down the flow of water (as does a detention or retention pond), but also can remove pollutants from the runoff water. The most important factor in the design and maintenance of constructed wetlands is hydrology (Mitsch and Gosselink, 1993). Without the proper water inflow and outflow, the newly created wetland will fail and be unable to accomplish its task of stormwater treatment.

Aims and Objectives

We are monitoring the performance of urban constructed wetlands in two settings, a constructed wetland incorporated into site development for a commercial facility and a series of constructed wetlands built into a recently renovated golf course that receives runoff from an adjacent urban area. Both sites are in West Lafayette, Indiana. The goal of long-term monitoring is to provide insight into seasonal and longer-term variations in trap efficiency, both as the basis for improved scientific understanding of constructed wetland processes and controls, and to form the basis for future improvements in design.

Study Areas

The commercial constructed wetland site occupies approximately 0.51 ha, with a water surface area of 0.26 ha and volume of 1300 m^3. This wetland is intended to treat the "first flush" of runoff, and so was designed to accommodate the volume of water corresponding to first half-inch of precipitation on the store's impervious surfaces (the parking lot and the rooftop). The mean depth of the constructed wetland is 0.5 m but this includes two deeper pools with a maximum depth of 1.8 m (Tatalovich, 1998). Conventional wisdom (which may not be correct) states that 90% of the annual pollutant load is transported in the runoff produced by the first 1.3 cm of precipitation (known as the first flush), and this has been shown to be true for the transport of most pollutants over impervious surfaces (Chang, 1994). At this commercial site, runoff that exceeds the first-flush equivalent is routed to a separate basin.

One motivating force behind use of a constructed wetland on this site was concern over potential impacts on a natural wetland (Celery Marsh) adjacent to the property. In addition to the constructed wetland, this site includes: elimination of a proposed auto care center, abstinence from chemical ice-clearing methods, and construction of additional ponds to treat stormwater runoff that could potentially include harmful pollutants. The constructed wetland receives runoff primarily from the 4.1 ha commercial parking lot, as well as minor additional input from an adjacent store, local access roads, and US Highway 52.

The golf course created wetlands are part of Purdue's new Kampen Golf Course and are positioned to intercept both runoff from much of the golf course and the adjacent urban area. The developed area includes two residential highways, a section of state highway, the parking lot of a motel, a gas station, and 200 residences. The water flowing through the Kampen Course eventually enters Celery Marsh, but prior to reconstruction this water flowed directly through drainage tiles and overland transport to the marsh, with no treatment. The golf course constructed wetlands serve several purposes: providing a water hazard and aesthetic component of the course, and enhancing environmental quality that can also be used in environmental education. Runoff from the urban area travels through three constructed wetlands prior to leaving the course. One particularly notable aspect of these constructed wetlands is that they have flourished even during long dry summer periods. Frequent watering of the greens and fairways, common on most courses, has the added advantage that it provides runoff and tile drainage to the wetlands throughout the summer.

Methodology

To determine the effectiveness of each constructed wetland in trapping potential pollutants, water samplers were installed at the inlet and outlet of the commercial constructed wetland (Figure 1), and at six locations in the golf course constructed wetland complex to track the progress of water as it enters the course, moves through the wetland system, and exits to the Celery Marsh. The samplers are equipped with ISCO® Submerged Probes that measure water levels, used in conjunction either with a weir or pipe of known geometry. The sampler uses these levels and the corresponding geometry of the sampling sites to calculate the flow into and out of the wetland. Each sampler also has a YSI® 600 Multi-Parameter Water Quality Monitor that measures dissolved oxygen, conductivity, temperature, and pH. The samplers record flow and water quality parameters every five minutes and are programmed to take water samples during storm events. Storm sampling is triggered in most cases by a change in water level, and at two locations, by rainfall intensity as measured with an automatic tipping bucket rain gauge. The trigger points were determined empirically, so that inlet and outlet samplers begin to sample at approximately the same time. The sampling programs for each sampler are split into two sections. The interval of time between samples in part A of each routine is closer together than those in the corresponding part B routines, so that sampling occurs more often during the "first flush." After that, the second stage

Figure 1. Sampling equipment at a constructed wetland. The laptop computer is downloading monitoring data from the sampler, and in the foreground is a set of 24 sample bottles for storm sampling.

of each routine samples at larger intervals to guarantee samples at times coinciding with the downward slope of the hydrograph.

Overall, the design of the experiment is to track flow and water quality into and out of the constructed wetlands continuously, both during storms and between storms, for a multi-year period. This allows for determinations of storm, seasonal and multi-year trends in constructed wetland trap efficiency. Trap efficiency can be defined in a number of ways, depending on the likely application of the results. In this work we are interested in concentration trap efficiency (percentage change in potential pollutant concentration between the inlet and outlet, both maximum and average values) and load trap efficiency (percentage change in potential pollutant load between the inlet and outlet for given points in a storm, for storm totals, and seasonally and annually). Selected samples from each precipitation event are analyzed by a Purdue University laboratory for total suspended solids (TSS), hardness, total Kjeldahl nitrogen (TKN), and total phosphorus (TP). These parameters are the same as those measured for seven other local sites as part of a larger analysis of water quality in rural and urban settings. In addition to the analyses performed at the Purdue laboratory, more complete chemical scans are performed once per season on selected samples by Heritage Environmental Services in Indianapolis, Indiana. The selection of tests is based on the pollutants that might reasonably occur at each site. The reason for this more complete scan is to determine whether any potential pollutants not routinely measured at the Purdue laboratory show up at unusually high levels. Any parameters that were not detected in the Heritage samples could potentially be excluded from future testing, but those parameters considered to be problems would need to be monitored on a consistent basis in the future.

Results and Discussion

To illustrate possible types of analyses and some major trends in the performance data, without reviewing the entire data sets available, this discussion includes three examples from the two sites. These include a complete storm record at the commercial site, between-storm sampling at the commercial site, and first-flush storm sampling at the golf course site.

Sample Storm at the Commercial Site

A 0.97 cm-storm occurred on 26 October 1997, with a double peak in intensity (Figure 2). As expected, the wetland acts to damp peak flows, so discharge values at the outlet slightly lag those at the inlet and are lesser in magnitude. Water temperature in the constructed wetland inlet is high and uniform (no diurnal variations) prior to the storm (Figure 3),

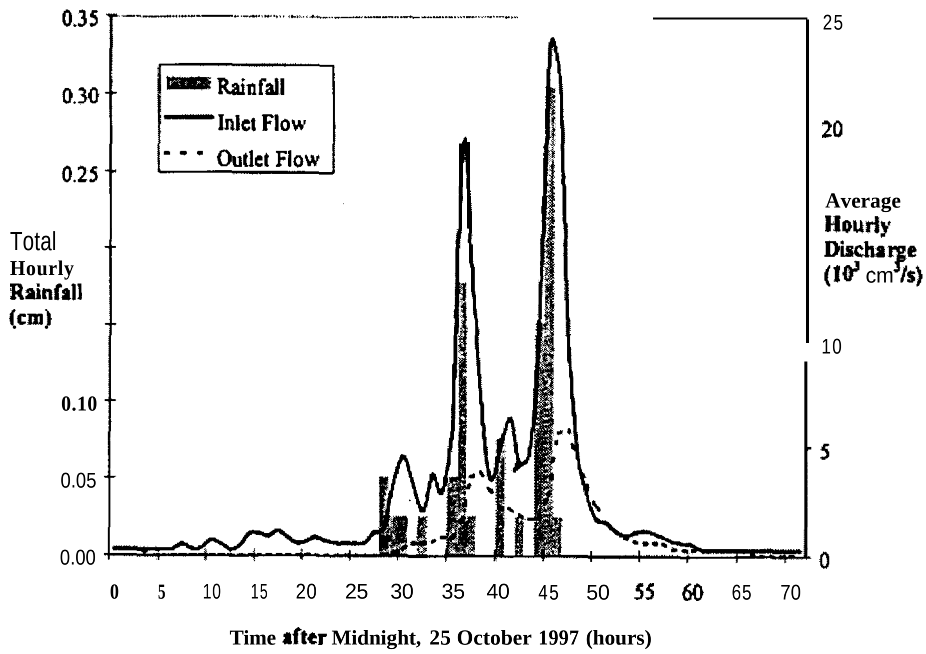

Figure 2. Rainfall and inlet and outlet runoff records for a storm event at the commercial site constructed wetland.

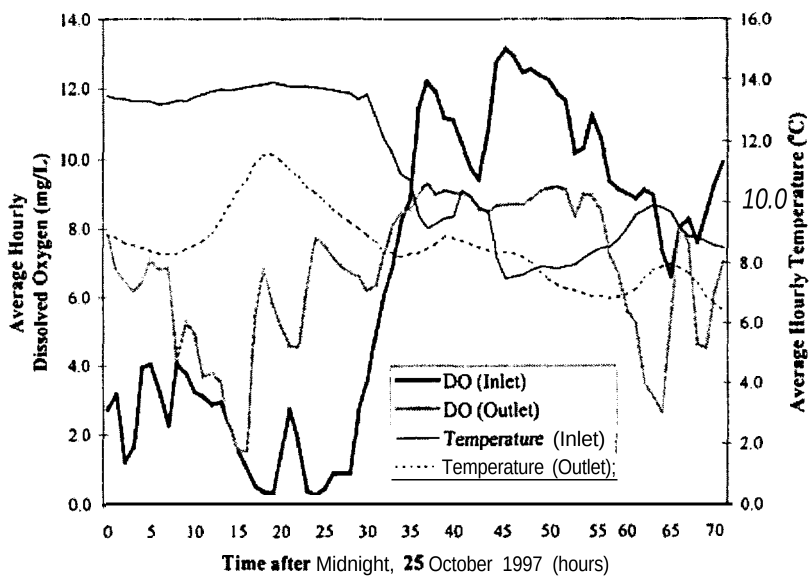

Figure 3. Dissolved oxygen and temperature records for the storm shown in Figure 1.

drops 6°C during the storm, and slowly climbs back 2°C in the 20 hours after precipitation stops. The outlet temperature shows a 4°C diurnal cycle prior to the storm, and a lower amplitude cycle after the storm. At the same time, the dissolved oxygen (DO) values climb during the storm (Figure 3). Inlet DO values vary within the 0 to 4 mg/L range before the storm, jump up to 9 to 13 mg/L during the storm, and fall during the 24 hours following the storm event. The outlet DO varies from 1 to 8 mg/L prior to the storm, is very stable between 8 and 9 mg/L during the storm, and has strong variations from 3 to 9 mg/L post-storm. High DO values during the storm are due to the increased mixing of the water, which causes oxygen to be introduced to the wetland, as well as the addition of "new" water that is higher in oxygen to the stagnant water.

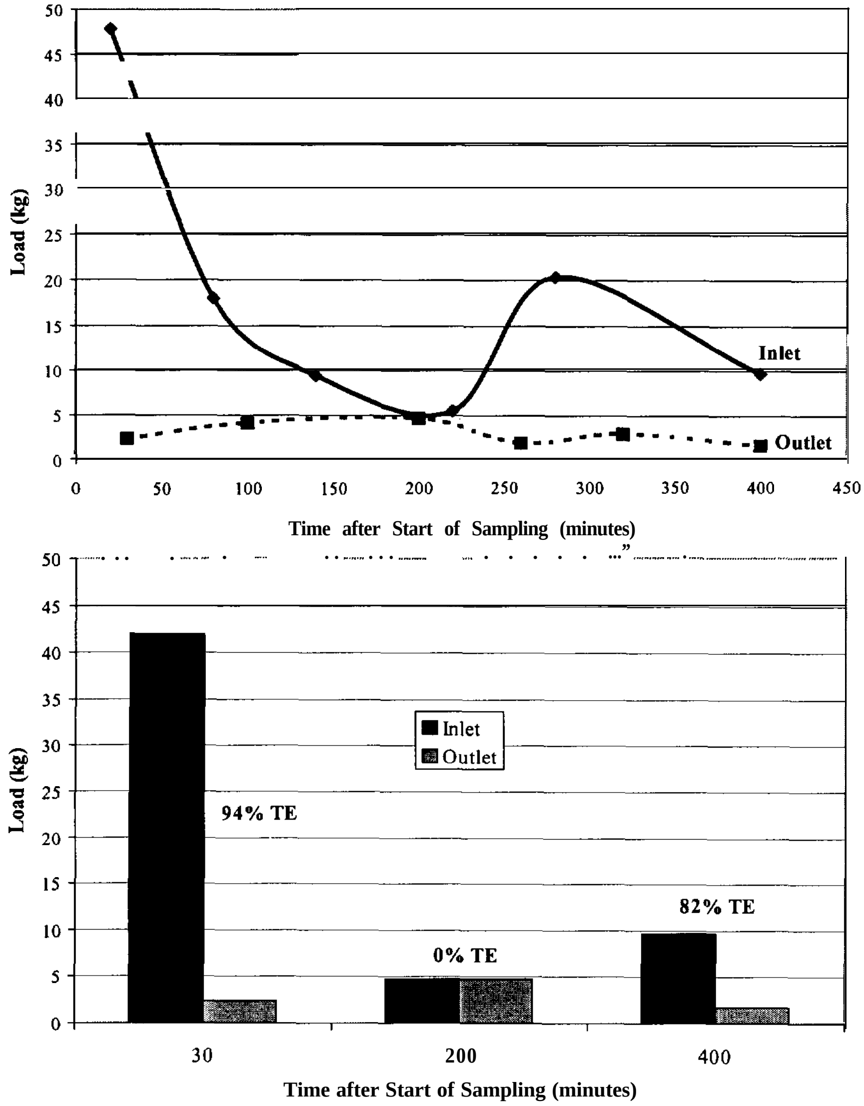

Figure 4. Total suspended sediment load for the storm shown in Figure 1 (upper), and calculated trap efficiency (TE) if only grab sampling had been used (lower). The actual load TE for the storm was 84%.

Initially, hardness data from the 26 October 1997 storm showed much higher values for the outlet than the inlet. This discrepancy relates to the movement of water through the wetland. Soon after the start of a storm, water begins to flow over the weir at the inlet and inlet sampling begins. This new runoff from the site has a low hardness, reflecting the naturally low hardness of rainwater. At the outlet, high hardness values show that the water initially being sampled is not new inlet water being displaced from the wetland; rather it is water that was stored in the concrete outlet box prior to the storm. Hardness values at the outlet fall throughout the storm, showing that hardness is lower in the wetland than in the concrete outlet box. Because hard water occurs when concentrations of Ca^{2+} and Mg^{2+} are high (Zumdahl, 1989), the concrete surroundings themselves can add to the hardness of the water. Ninety-five percent of all concrete used is made from Portland cement, which is prepared using finely ground limestone (Mindess and Young, 1981). The cement is made into concrete using admixtures such as calcium chloride. Also, the interaction of the surface water with groundwater, which in this geographic location is very hard due to infiltrating rainwater that dissolves the calcite-rich till from limestone in the region, can add to the hardness of the water in the wetland (Davis and Cornwell, 1991).

The hardness data suggest that the outlet record probably does not include water that enters and exits the wetland during the same storm. Other studies (e.g. Bhaduri, et al., 1997) have shown through chemical load distributions that the inflow and outflow from a basin are actually two different water masses, except in extreme storm events. The only way that the same water could appear at the inlet and outlet during the same storm would be if the inflow sheeted over the water in the basin, arriving at the outlet without significantly mixing with the water stored in the wetland prior to the storm; or if the storm produced enough water to completely displace the volume of water in the wetland.

Total suspended solids (TSS) concentration data and flow values for the storm are used to calculate TSS loading values, which depict the effect of the basin in reducing the overall sediment load. Total loads depict the actual physical amount of sediment entering the wetland and are important for planning activities such as dredging. TSS load values for the inlet are larger than the outlet (Figure 4). The inlet values start high, dip down, and then increase again. This indicates that the initial runoff has “first flush” (high load) characteristics, and then the load input rate decreases. A second, lower peak later in the storm could be the result of the later pulse of higher rainfall intensity (Figure 2). The values of TSS at the outlet remain fairly uniform throughout the storm. The initial value presumably represents between-storm ambient TSS loading in standing water in the wetland. During the storm, the increase in flow creates more turbulence, which can stir up some of the bed sediment, slightly increasing the TSS concentration and, therefore, the load. More importantly, though, the outlet values are lower than those for the inlet; thus there is a net decrease in TSS loading from the inlet to the outlet for this particular storm. In one sense, this traditional approach is a valid efficiency measure because the water going out is compared to that going into the wetland, but in another sense it is a skewed picture because the new inlet water is being compared with “old” outlet water that arrived in the basin during a previous storm (Bhaduri, et *al.,* 1997).

Multiple storm sequence sampling will provide a better view of overall trap efficiency (TE) than a single storm, just as a complete storm record is better than a grab sample. Standard grab samples do not always lead to accurate trap efficiency calculations (Figure 4). If one sample were taken each from the inlet and the outlet at exactly same time, the data could show a very high trap efficiency (30 minutes), no trap efficiency (200 minutes), or a fairly high trap efficiency (400 minutes). The overall load TE for this analysis was 84%. This is one of the reasons that this particular study samples several times after the start of a storm -- to bridge the gap between standard grab samples and actual events within the wetland. Continuous monitoring provides a more complete record of the constructed wetland’s activity, more accurately depicting the trap efficiency of the wetland. From conductivity data, during the monitoring period, 137 kg of dissolved load entered the basin, and 59 kg left the basin, for a total dissolved solids (TDS) load TE over the storm of 57%. Further analysis of many storms can be used to determine an overall trap efficiency over longer periods of time. This type of analysis could be used to determine the effects of different storm intensities, seasonal variations, and increased urbanization in the area.

Detailed Chemical Scan at the Commercial Site: Between Storm Conditions

Samples for a detailed chemical scan were taken on 17 December 1997 using the sampler’s grab sampling mechanism. At this time, there had not been a precipitation event in a couple of weeks, so these samples represent between-storm conditions in the wetland. Although these samples were tested for many possible pollutants, only a few were detected (Table 1).

Parameters which show reductions between the inlet and the outlet were chloride, sulfate, ammonia nitrogen, calcium, magnesium, sodium, silicon, strontium, and total dissolved solids (TDS). For instance, chloride levels fell from 210 to 160 mg/L, calcium levels fell from 95 to 54 mg/L, and strontium levels fell from 0.16 mg/L to below the detection level of 0.10

Table 1. Detailed chemical scan of the commercial site constructed wetland. All values are mg/L.

Parameter	Inlet	Outlet	Detection Limit
Chloride	210	160	*2.5*
Sulfate	49	*37*	1.3
Nitrogen, Nitrate-Nitrite	0.12	0.11	0.01
Nitrogen, Ammonia	0.21	0.14	0.12
Chemical Oxygen Demand	*18*	*28*	*10*
Aluminum	*BDL*	*1.3*	*0.10*
Calcium	*95*	*54*	0.10
Iron	*0.33*	*1.7*	0.70
Potassium	*2.5*	*2.7*	*0.10*
Magnesium	*28*	15	0.10
Manganese	*0.32*	*0.24*	0.10
Sodium	110	*85*	0.10
Silicon	5.1	*3.0*	0.10
Strontium	0.16	BDL	0.10
Total *Organic Carbon*	*BDL*	*4.2*	7.0
Total Phosphorus	*BDL*	*0.10*	*0.03*
Dissolved Solids	*720*	*490*	10
Total Suspended Solids	*4*	*13*	1

Notes: Italicized parameters are those which have an outlet value > inlet value.
BDL = below detection limit

mg/L. Also, TDS levels fell from 720 to 490 mg/L. When compared to the values calculated using conductivity data from the sampler, these values are slightly higher than the values calculated for the 26 October 1997 storm event. The maximum TDS values calculated for the inlet and the outlet were, respectively, 568 and 365 mg/L, with average values around 337 and 263 mg/L. The higher between-storm values could be a result of the ability of sediments to dissolve in the wetland waters. Reductions in values between the inlet and the outlet indicate removal of certain pollutants within the wetland and also suggest that at the beginning of a storm, the outlet values will be lower than those of water near the inlet. Because of this, the best TE should be at the start of a storm, which is shown in the 26 October 1997 storm chemical data.

Not all of the detectable parameters were lower at the outlet than at the inlet. The ones that were actually larger at the outlet than at the inlet were: chemical oxygen demand (COD), aluminum, iron, potassium, total organic carbon (TOC), total phosphorus (TP), and total suspended solids (TSS). The increase in TSS is interesting, and may be the cause of increases in adsorbed pollutants. This could be attributable to the lack of growth of plants in the middle of December. Plants slow flow within the wetland, allowing sediments in the water to settle, and plants have the ability to take into their roots pollutants carried by the sediments (Pond, 1995). Because of this, as the plants die, they may release the sediments and pollutants trapped earlier in the year, as well as releasing products of the decay of the organic matter. Aluminum, iron, potassium, and phosphorus could have been attached to these sediments, especially the finer particles. Findings such as these agree with previous studies that noted a distinct reduction in the performance of stormwater wetlands in winter months (Oberts, 1994; Ferlow, 1993). Not only does plant death have an effect, but also the formation of ice on the water surface can scour the margins and resuspend the sediments and the pollutants that they carry (Oberts, 1994).

Detailed Chemical Scan at the Golf Course Site

First flush samples were collected for detailed chemical analysis during the first pulse of runoff from a storm in November 1998 and a second storm in June 1999 (Table 2). In November 1998, 14 water quality parameters declined in terms of a comparison between the urban input (Site 1) and the golf course output (Site 6). Four water quality parameters improved between the urban input and the water exiting the course during the same storm. This suggests that the constructed wetlands were not working well soon after initial construction, during the late fall. However, key parameters such as ammonia and nitrate-nitrite nitrogen and pesticide levels were either decreased as the watercirculated through the golf course wetlands or were not detectable at either sampling site.

A distinctly different pattern of results is apparent in the June 1999 sampling (Table 2). Fifteen water quality parameters improved between the urban input and the water exiting the course, and only 4 parameters declined. This suggests that the golf course's created wetland system is functioning well to improve the water quality in the late spring when wetland plants have become established. Two parameters of particular interest for a golf course are nitrate-nitrite N and ammonia-N, which were undetectable in water exiting the course, but at 2.1 and 31 ppm, respectively, in water flowing onto the course.

Table 2. Detailed chemical scan of the golf course site constructed wetland, selected parameters. All values are mg/L.

		November 1998			June 1999		
Parameter	Detection limit	Site 1 Urban runoff	Site 6 Created wetland outlet	increase/ decrease	Site 1 Urban runoff	Site 6 Created wetland outlet	increase/ decrease
Simazine	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Atrazine	0.10	BDL	BDL	BDL	0.1	BDL	-91%'
Oil and Grease	5	BDL	BDL	BDL	BDL	BDL	BDL
Chloride	2.5	8.6	22	+156%	32	20	-38%
Sulfate	2.5	11	55	+400%	18	31	+72%
Nitrogen nitrate-nitrite	0.01	1.1	0.06	-95%	2.1	BDL	-100%"
Ammonia nitrogen	0.12	0.23	BDL	-52%'	31	BDL	-100%*
Chem. 0, Demand	10	40	37	-8%	480	25	-95%
Mercury	0.0002	BDL	BDL	B D L	BDL	BDL	BDL
Total Organic Carbon		8.2	10	+22%	240	1.6	-99%
Phosphorus	0.03	0.19	0.17	-11%	0.32	0.08	-75%
Dissolved Solids	10	91	270	+197%	240	220	-8%
Suspended Solids	1	17	290	+1606%	8	2	-75%
Silver	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Aluminum	0.10	0.31	5.8	+1771%	1.8	0.16	-91%
Arsenic	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Calcium	0.10	29	61	+110%	40	34	-15%
Cadmium	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Chromium	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Copper	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Iron	0.10	0.51	4.7	+822%	1.6	0.26	-84%
Potassium	0.10	2.3	7.8	+239%	2.2	0.37	-83%
Magnesium	0.10	7.1	24	+238%	9.9	28	+183%
Manganese	0.10	BDL	0.21	+133%	0.28	BDL	-64%
Molybdenum	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Sodium	0.10	4.5	6.8	+51%	6.5	8.7	+34%
Nickel	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Lead	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Selenium	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Silicon	0.10	2	14	+600%	2.0	4.8	+140%
Tin	0.10	BDL	BDL	BDL	BDL	BDL	BDL
Titanium	0.10	BDL	0.14	+56%*	BDL	BDL	BDL
Zinc	0.10	BDL	BDL	BDL	0.38	BDL	-74%'

BDL = Below Detection Limit

. where contaminant was BDL, the detection limit was used for % increase/decrease calculations

No unusually high levels of any of a wide array of potential pollutants, including pesticides and metals, were detected at the golf course sampling sites. However, atrazine was detected in water exiting the neighborhood and entering the golf course (Site 1). Surprisingly, even from the urban runoff there was no measurable oil and grease. It is reassuring to note that heavy metals of concern, such as mercury and lead, are below detection limits in all samples.

Conclusions

Constructed wetlands can potentially be used to improve NPS pollution management in urban areas. Although finding space for constructed wetlands can be a challenge in developed areas, these management tools can be incorporated into the design of new or renovated commercial and industrial facilities. In some cases, they can be added to recreational facilities such as parks and golf courses. In each of these cases, good initial design and attention to continued water supply for long-term wetland survival is critical.

The constructed wetland monitoring program in West Lafayette, Indiana, includes both commercial and golf course constructed wetlands. Selected results presented here illustrate the complexity of developing a program to evaluate performance of such wetland systems. Traditional grab sampling can provide misleading results compared to continuous sampling, and it is clear that apparent trap efficiency varies both within storms as well as between seasons. The type of complete picture of constructed wetland performance that is needed to improve design and enhance understanding of chemical and biological processes in constructed wetlands can be approached by continuous monitoring through several years. Initial data suggest that the constructed wetlands studied here are generally performing well to reduce loads and concentrations of a range of urban NPS pollutants, particularly during spring and summer storm events after wetland vegetation has become established. However there is also a strong indication that trap efficiencies are much lower, and in some cases negative, during winter months. The implications of this depend on the context provided by the receiving area.

Constructed wetlands also provide important benefits beyond water quality control. They provide aesthetic diversity in urban settings, they represent islands of habitat types that are generally absent or underrepresented in older developed areas, and they provide important local educational resources in urban areas. Overall, constructed wetlands should be considered as a potential element of urban retrofit projects, if there are situations where water supply is available to maintain wetland hydrology.

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Advanced Identification (ADID) Techniques Used to Protect Wetlands and Aquatic Resources in a Rapidly Growing County

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Abstract

McHenry County, Illinois, approximately 40 miles northwest of Chicago, is one of the fastest growing counties in the state. It also is home to many valued wetland and stream communities that are threatened by the impacts of new development. Because of this, county government officials, with funding from the U.S. Environmental Protection Agency, sought the assistance of resource experts from various local, regional, state, and federal agencies. Their task was to assess the quality of the aquatic resource and to develop strategies for improved wetland protection. The project initially involved the development of an up-to-date countywide inventory of wetlands, lakes, and streams. This inventory showed that over 11% of the county was covered with wetlands and waterbodies. These aquatic resources then were evaluated and rated based on the habitat, water quality, and stormwater storage functions that they provided. While only a small fraction of the total number of wetlands -- about 11% -- of the county's wetlands were designated high quality, these wetlands represented over 60% of the total wetland acreage. Inventory and assessment data were transferred to a customized CD-ROM mapping tool to provide ready access to project information by resource managers, planners, and local governments. The project team also developed a protection strategy for aquatic resources that was tied to the results of the Advanced Identification (ADID) study. In particular, it identified four critical protection components: improved education, regulations and best management practices, acquisition, and restoration. Though the ADID study is only recently completed, there are strong indications that this protection strategy is being taken seriously by officials in the county.

Background

McHenry County, Illinois lies approximately 40 miles northwest of Chicago along the Wisconsin border. Reflecting a history of glacial activity, McHenry County possesses an abundance of wetland types in a variety of physical settings. Predominant wetland types include palustrine, lacustrine, and riverine systems. Palustrine wetlands are found in a wide variety of geographic settingsand terrains in the county and include marshes, bogs, fens, wet prairies, forested wetlands, and ponds. Lacustrine wetlands are less common. They are found mostly in eastern portions of the county and are exemplified by the wetlands of the Fox River - Chain 0' Lakes. High quality rivers and streams, and associated riverine wetlands, are relatively common. In fact, McHenry County has some of the highest-quality stream ecosystems in Illinois, as exemplified by the Kishwaukee River and its tributaries.

While predominantly rural, McHenry County is one of the fastest urbanizing counties in the state. From 1990 to 1998, its population grew by 31.5% to 240,945. Population is forecast to grow to nearly 362,000 by 2020, an increase of an additional 50%. This rapid population growth has raised concerns over possible adverse impacts on the county's wetlands, lakes, and streams.

Historically, wetland and stream protection measures in McHenry County have included federal regulations, local government ordinances, and acquisitions by government agencies, primarily the McHenry County Conservation District and the Illinois Department of Natural Resources. However, with the recent rapid pace of urban development, unacceptable loss and/or degradation of wetlands and aquatic resources have been observed. Concerned over the possible environmental effects of rapid growth, the county board invited the U.S. Environmental Protection Agency Region 5 (EPA) to perform an "advanced identification" (ADID) study of its wetlands and aquatic resources.

An ADID project can have several objectives. One objective is to shorten permit processing, while providing increased predictability to the Corps of Engineers regulations under Section 404 of the Clean Water Act. ADID also provides information that can be used by state and local governments to aid in zoning, permitting, or land acquisition decisions. Another objective of ADID is to provide information to agencies, landowners, and private citizens interested in restoration or acquisition of aquatic sites.

Approach

The ADID study was initiated in 1995, under the coordination of the Northeastern Illinois Planning Commission (NIPC). The study was a cooperative effort among federal, state, and local agencies to inventory, evaluate, and map high-quality wetland and aquatic resources in the county. From the federal perspective, the primary purpose of this ADID study was to designate wetlands or other waters of the United States that are unsuitable for discharge of dredged or fill material. From the local perspective, the purposes of ADID were to improve the overall protection mechanism for wetlands via improved local regulation, improved predictability in the permitting process, identification of potential mitigation/restoration sites, and identification of potential sites for acquisition.

The scope of work for the ADID project included the following tasks:

- form a Technical Advisory Committee and a Planning and Policy Committee;
- develop ADID objectives for McHenry County and a strategy for protection and management;
- identify and map existing wetlands and aquatic resources;
- develop an evaluation methodology for identified functions of wetlands and aquatic resources;
- apply evaluation methodology utilizing Geographic Information System (GIS) technology and field inspection;
- map ADID sites for public review;
- develop a CD-ROM tool that contains both the project data and a customized GIS interface for display, query, and mapping; and
- produce a final report and brochure and conduct a workshop for local governments, landowners, and consultants.

The Technical Advisory Committee and the Planning and Policy Committee were formed soon after initiation of the project. There were two general purposes for these committees: 1) provide technical and policy assistance to NIPC and EPA, and 2) provide a forum for educating local interest groups regarding the value of wetlands and aquatic resources in the county.

The principal role of the Technical Advisory Committee was to advise project staff on scientific issues, particularly the development of evaluation methodologies for wetlands, lakes, and streams. Technical committee members provided expertise in wetland biology, soil science, hydrology, engineering, water quality, and computerized mapping. Technical committee members contributed substantial time evaluating wetlands, both in the office and the field. The technical committee consisted of the following invited agencies and organizations:

- U.S. Environmental Protection Agency, Region 5
- U.S. Army Corps of Engineers, Chicago District
- U.S. Department of the Interior, Fish and Wildlife Service, Chicago-Metro Wetlands Office
- USDA, Natural Resources Conservation Service
- Illinois Department of Natural Resources

- McHenry County Department of Planning and Development
- McHenry County Conservation District
- McHenry County Soil and Water Conservation District
- Fox Waterway Agency
- Northeastern Illinois Planning Commission

The principal role of the Planning and Policy Committee was to advise project staff on policy, particularly the determination of wetland functions important to McHenry County. The policy committee also provided advice on the development of a wetland protection and management strategy. The policy committee included all of the members of the technical committee as well as members of the following organizations:

- Homebuilders Association of Greater Chicago
- Illinois Audubon Society, McHenry County Chapter
- Illinois Environmental Protection Agency
- Land Foundation of McHenry County
- McHenry County Board
- McHenry County Defenders (a local environmental group)
- McHenry County Farm Bureau
- McHenry County Municipal Association
- McHenry County Realtors Association
- McHenry County Stormwater Committee
- Openlands Project (a regional open space advocate)

Developing an Aquatic Resource Inventory

Detailed inventories of wetlands, lakes, and streams were developed early in the project. Two principal existing inventories were considered for identifying and mapping wetlands: the National Wetland Inventory (NWI) developed by the US. Fish and Wildlife Service with the assistance of the Illinois Department of Conservation (1986) in the early 1980s, and an inventory by the Natural Resources Conservation Service (NRCS) that was being completed in McHenry County just as the ADID project began. While neither inventory was adequate alone (the NWI was becoming dated and the NRCS inventory, while more recent, and only a data set, focused principally on agricultural areas), in combination they served as a good starting point. In finalizing the inventory, numerous revisionsand improvements were made based on reviews of aerials photos, field checks, and the knowledge of local experts.

The resultant inventory identified 2,535 wetlands, including lakes, covering 37,846 acres. The inventory identified an additional 1,250 farmedwetlands covering 3,839 acres. In total, there were 3,785 wetlands in all categories covering 41,685 acres, or nearly 11% of the county.

Lakes were identified as a subset of wetlands. Specifically, lakes were distinguished based on a criterion of 20 acres or more of open water. Fifteen such lakes were identified (excluding gravel pits).

Type	Number	Acreage	Percent of County Area
Wetland	2,518	33,003	8.4
Farmed Wetland	1,250	3,839	1.0
Lake	15	3,584	0.9
River	2	1,259	0.3
Total	3,785	41,685	10.6

Streams were identified and mapped based on an inventory developed by the EPA. EPA's Stream Reach File, Version 3 (1:100,000 scale), with minor revisions, provided an accurate and complete inventory of county streams. The inventory included over 570 miles of streams ranging in size from small, unnamed headwaters to large rivers like the Fox and Kishwaukee.

Evaluation of the Functions and Quality of Aquatic Resources

As the first step in developing a wetland evaluation methodology, members of the policy committee were asked to identify wetland and aquatic resource functions that were important to McHenry County. After considerable discussion, the committee recommended that the following functions be considered and evaluated: biological/habitat functions, water quality mitigation functions, stormwater storage functions, and groundwater functions. These functions then were evaluated and refined by the technical committee. Ultimately, it was concluded that groundwater functions of wetlands, while having important water supply implications, could not be evaluated because of insufficient data.

The project team and advisors then proceeded to develop evaluation criteria and methodologies for the following general categories: *biological/habitat functions* and water *quality/stormwater* storage *functions.* The development of a methodology for identifying high-functional-quality wetlands in McHenry County relied both on existing wetland evaluation methodologies and the technical expertise of members of the technical advisory committee. The resultant methodology builds on a methodology used in nearby Lake County, Illinois (Dreher, et al., 1992) as well as other documented methodologies, particularly the Wetland Evaluation Technique (WET) manual (Adamus et al., 1987), the Oregon Method (Roth et al., 1993), and the Minnesota manual (U.S. Army Corps of Engineers, 1988).

The methodology was designed to accomplish two objectives: 1) identify the functions that individual wetlands were performing, and 2) identify wetlands of such high quality that they merit special consideration for protection strategies. The evaluation of the identified functions for individual wetlands can be very complex and some of the referenced methodologies describe fairly elaborate approaches to perform thorough evaluations. However, because of the large number of wetlands to be considered in McHenry County, it was necessary to adopt a simpler evaluation procedure. The resultant methodology isfullydocumented in the final project report, "Advanced Identification (ADID) Study, McHenry County, Illinois" (NIPC et al., 1998). An overview of the evaluation criteria follows.

Biological functions include wildlife habitat, floristic diversity, stream aquatic habitat, and lake aquatic habitat. Wetlands were considered *high quality* for this function if they met one of several criteria. These criteria included:

- the presence of threatened or endangered plant or animal species;
- designation in the Illinois or McHenry County Natural Areas Inventory (NAI);
- field evaluation as a grade A, B, or C wetland community following NAI methods;

- streams with Index of Biotic Integrity (IBI) scores of 41 or greater;
- streams with high quality physical habitat; and
- healthy lake ecosystems with rich/diverse fish and plant communities.

Wafer *quality/stormwater storage* functions include shoreline and streambank stabilization, sediment and toxicant retention, nutrient removal and transformation, and stormwater storage and hydrologic stabilization. In order to be designated *high functional* value for water quality/stormwater functions, wetlands were required to meet three of the four following criteria:

- presence of stabilizing vegetation adjacent to an open waterbody or perennial stream;
- surface area larger than five acres and having characteristics indicating the propensity for sediment/toxicant retention;
- surface area larger than five acres, upstream of a lake or impoundment, and having characteristics indicating the likelihood of nutrient removal/transformation; or
- surface area larger than five acres, at least 50% outside the floodplain, and having characteristics indicating significant stormwater retention.

Alternatively, wetlands could be designated *high functional value* for water quality functions if they provided individual water quality functions adjacent to or upstream of wetlands, lakes, or streams that provide high quality habitat.

Individual wetlands and waterbodies were evaluated using a three-step procedure of GIS screening; aerial photo, map or desk-top evaluation; and field evaluation (as needed). Based on this evaluation, it was determined that 154 wetlands totaling 17,489 acres, or about 42% of the county's entire wetland area, met the criteria for high-quality habitats. Most of the high-quality wetlands tended to be large parcels, averaging 114 acres in size in comparison to the average wetland size of 11 acres countywide. An additional 274 wetlands totaling 8,292 acres (average size of 30 acres) met the criteria for high value for stormwater and water quality functions. Thus, while a relatively small number of wetlands (about 11%) were designated high quality or high functional value, these wetlands represent over 60% of the total wetland acreage.

Classification	Number	Percent of all Wetlands	Acreage	Percent of County Area	Percent of all Wetland Area
High Quality Habitat	154	4.0	17,489	4.5	42.0
High Functional Value	274	7.2	8,292	2.1	19.9
High Quality Lake	7	0.002	1.346	0.3	3.2

Of the 15 inventoried lakes, seven were determined to be high quality. A total of 572 miles of stream were evaluated and 170 miles (or nearly 30%) were designated high quality. Interestingly, high-quality stream segments were found on 18 different named streams and rivers scattered throughout the county.

Using ADID for Protection and Restoration

The ultimate measure of success for a project like the McHenry County ADID study is how it contributes to the protection and restoration of aquatic resources. With this in mind, the project scope included a work element to develop a strategy for protection and management of aquatic resources. With the assistance of the advisory committees, the project team developed a four-part strategy involving:

- improved education of local government officials, landowners, and the public;
- effective regulations and best management practices;
- expanded acquisition of aquatic sites and buffers; and
- restoration of degraded sites.

This strategy, which is described in detail in the project report (NIPC et al., 1998), is summarized below. Also described are some recent protection and management activities, although it is still too early to judge the long-term success of the project.

Improved Education: Educational initiatives are critical to improve awareness of wetlands and aquatic resources among local citizens, land owners, and elected officials. Improved awareness can enhance local support for protection, acquisition, and restoration programs.

- A 12-page brochure, *McHenry County's Wetlands, Lakes, and Streams,* was developed to educate the public and local officials about the value of wetlands and aquatic resources in their communities. The brochure also discussed the results of the ADID study and identified additional sources of information and agencies that can provide help. Over 1000 copies of brochure have been distributed by participating agencies, such as the county soil and water conservation district.
- Maps and information for all ADID sites were made available on a "user-friendly" CD-ROM. The CD-ROM includes simplified mapping software developed from a sophisticated GIS tool. The software enables querying and screening of various wetland characteristics at different geographic scales throughout the county. It also enables printing out detailed information on individual wetlands. Over 100 copies of the CD-ROM have been provided to local officials, consultants, and landowners in the county.
- The message of wetland, lake, and stream protection also is being carried to local officials and the public by county-based environmental groups and consortiums called "ecosystem partnerships" that have been established for the two main river watersheds in the county (the Fox and the Kishwaukee). ADID will be a useful tool in aiding the efforts of these organizations.

Effective Regulations: Effective regulations are needed to minimize the effects of new development on aquatic resources. Specifically, improved regulations are needed to fill in the gaps in existing federal, state, and local regulatory programs. It was the conclusion of both the ADID team and the *McHenry County Comprehensive Stormwater Managemenf Plan* (McHenry County, 1996) that improved regulations are needed to address concerns such as buffers and setbacks, depressional storage volumes, pretreatment of stormwater runoff, and effective environmental mitigation for unavoidable disturbances.

- Current federal regulations authorized under Section 404 of the Clean Water Act require a permit for the discharge of dredged or fill material into wetlands or other waters of the United States. Federal guidelines also authorize the EPA and the Corps of Engineers to identify in advance of specific permit requests, aquatic sites that will be considered as areas generally unsuitable for disposal of dredged or fill material. The Chicago District of the Corps has indicated that it will apply this discretionary authority to high-quality habitat and high- functional value sites in McHenry County. The Corps also generally will require an individual permit (which allows public input) for proposed modifications of ADID sites.
- Stream and wetland regulations, based on a model ordinance developed by NIPC, also have been adopted by a number of local governments in the county. These regulations are intended to complement the federal regulations by discouraging development in buffers and setbacks adjacent to wetlands, lakes, and streams and requiring pre-

treatment of stormwater discharges. The City of Woodstock, the county seat, recently applied its wetland protection regulations in a residential development review that resulted in an innovative conservation design around a large wetland. Not only will the wetland be avoided, but the site design calls for clustering of homes and buffers adjacent to wetland areas. Also, drainage swales and natural landscaping will be incorporated on upland portions of the site to reduce hydrologic and water quality impacts of the development.

- ADID team members have worked closely with staff and consultants to the McHenry County Stormwater Committee in the development of a countywide ordinance for new development. It has been recommended that the countywide ordinance include provisions for stream and wetland protection that complement, but do not duplicate, federal regulations. While the ordinance adoption process has been challenged by financial constraints and political changes in the county, it appears likely that significant stream and wetland protections will be added to existing county and municipal regulations.

Acquisition: Acquisition of important wetlands and stream corridors is one of the best ways to assure their long-term protection. In fact, recent experience indicates that these areas are becoming high priorities for public land acquisition. Information developed in the ADID study, particularly the identification of high-quality habitats and high-functional-quality wetlands, will be valuable to land acquisition agencies, including park districts, the McHenry County Conservation District, the Illinois Department of Natural Resources, and local land trusts, in assessing acquisition priorities. In a recent example, the Plan Commission of Nunda Township in east-central McHenry County is developing a comprehensive land use plan that will utilize ADID maps to identify areas to be preserved as open space.

Restoration: Restoration of degraded wetlands, lakes, and stream corridors, and ongoing management of higher quality sites, are critical challenges for land management agencies. Management is needed to counteract the effects of disturbances such as site fragmentation, elimination of fire, invasive species, and hydrologic alterations. Notably, the McHenry County Conservation District has been a regional leader in restoring degraded streams and wetlands. The ADID data base will be very useful in identifying appropriate sites to continue this restoration. The availability of GIS data bases and mapping, particularly in conjunction with other digital data such as soils maps and data on seeps and springs, will greatly facilitate this objective.

Lessons Learned

ADID was a valuable experience in McHenry County that generally met its identified objectives. In considering ADID studies in other areas, there are several important lessons one can learn from the McHenry County experience.

1) *Engage localgovernment sponsors and keep them informed throughout the project.* The McHenry County ADID began after the county board passed a resolution soliciting EPA's assistance. County staff and elected officials were invited to participate on advisory committees. When support appeared to waver at critical points in the process (e.g., staff changes and budget difficulties at the county), the project team reached out by convening special meetings reminding county officials of the benefits of the project with respect to adopted county objectives.

2) *Conduct an open study process involving both traditional supporters of stream and weflandprofecfion efforts and potential adversaries.* Groups ranging from environmental organizations to developers and the agricultural community were invited to participate on advisory committees where issues and approaches were openly discussed. When a public meeting was held to present project results, over 200 individuals attended. The vast majority of those expressing opinions indicated support for ADID objectives and procedures, even though some had concerns over the ramifications of federal wetland regulations.

3) *Utilize fhe expertise and local know/edge of federal, state, and local resource agencies.* While EPA contracted with NIPC to coordinate the project, staff from numerous resource agencies contributed invaluable expertise in hydrology, soils, aquatic ecology, and botany. They also contributed countless hours in evaluating field sites. Scheduling such assistance from multiple agencies resulted in some time delays. However, without these voluntary contributions, the project could not have been completed.

4) *Define wet/and and aquatic resource functions from a multi-objective perspective.* While there is a tendency sometimes to focus on just the habitat and recreational values of wetlands, lakes, and streams, it is important to consider a broader range of benefits to maximize local buy-in to the process. The McHenry County ADID specifically considered stormwater and water quality functions that were identified as being important in local plans, such as the *McHenry County Comprehensive Stormwater Management Plan.*

5) *Distribute end-products in user-friend/y formats.* While ADID was a highly technical and complex project, efforts were made to provide products that were readily understandable by local governments, land owners, consultants, and the public. The product receiving the most interest was the CD-ROM containing ADID data, as well as a user-friendly GIS-based interface for querying and mapping. The CD-ROM promises to be much more useful than conventional paper maps.

6) *Engage the local press in covering the project.* Limited attempts were made to inform the local press during the course of the study. While there was some resultant news coverage in local newspapers, particularly around the time of the public meeting, this coverage was not particularly effective in informing the public about the benefits of wetlands and the importance of the ADID study. Focused efforts, such as targeted press releases, probably would have improved the frequency and quality of coverage.

Conclusions

The ADID study provides valuable information to advance the protection and restoration of wetlands and aquatic resources in McHenry County. It can aid residents and organizations desiring to protect high-quality resources or restore sites that have been degraded. It can inform landowners and developers about an appropriate course of action when they are considering disturbances in or adjacent to high-quality sites.

While the final ADID products have been available for only a short time, it is apparent that they will greatly facilitate ongoing efforts to educate county residents and officials, protect streams and wetlands from the effects of new development, preserve sensitive stream corridors and wetlands as public land, and restore degraded sites. While the ultimate success of county stream and wetland protection initiatives will depend on the will of landowners and local government officials, no one will be able to blame wetland loss on inadequate information.

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Local Government Involvement in Mitigation Banking

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Abstract

Mitigation banking is a valuable tool that can be used by local officials to achieve wetlands restoration and other local goals. Mitigation banks can be established by local governments to provide compensation for wetland losses that result from development projects. There are different strategies that local governments can use to establish a mitigation bank, depending upon their goals and objectives. The success of a mitigation bank is dependent upon several factors, ranging from bank location to the availability of funding. The Environmental Protection Agency conducted a survey of local jurisdictions to identify the different strategies that were utilized for effective development and implementation of mitigation banking. The findings of the survey are presented in case-studies that characterize the approaches that were used by local governments to achieve their mitigation banking goals and objectives.

Introduction

Mitigation banking is defined in the Federal Mitigation Banking Guidelines[1] as "wetland restoration, creation, or enhancement for the purpose of compensating for unavoidable wetland losses in advance of authorized impacts to similar resources." Under Section 404 of the Clean Water Act, applicants for permits must first avoid and minimize all impacts to wetlands and other waters of the United States. If there are still impacts, then applicants must provide compensatory mitigation through the restoration, creation, and the enhancement of similar type of aquatic resources. This "sequencing process" under the Section 404(b)(l) guidelines is a central premise of the Section 404 regulatory program, and mitigation banking can play a role in providing compensatory mitigation for unavoidable wetlands losses.

As a general matter, on-site and in-kind mitigation is preferred under the Section 404 Program. However, in those circumstances where it is determined, on a case-by-case basis, not to be practicable, then off-site, in-kind mitigation is acceptable.[2] Off-site mitigation can be accomplished using a federally-approved mitigation bank. Since the use of mitigation banking to offset permitted wetlands losses began in earnest in the early 1990's, local governments have been involved in developing banks to restore and replace lost wetlands functions and values within their jurisdictions. By simplifying the process for compensating for unavoidable wetlands losses, appropriate use of the banking concept can improve both permitting efficiency and environmental protection.

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[1] *Federal Guidance for the Establishment, Use and Operation of Mitigation Banks;* Notice. Federal Register, Volume 60, No. 228, pages 58605-58614, November 28, 1995.

[2] Memorandum of Agreement between the EPA and the Department of the Army Concerning the Determination of Mitigation Under the Clean Water Act Section 404(b)(l) Guidelines (February 6, 1990)

Mitigation Banking Objectives

- Local needs are best met when there are clear objectives and goals for establishing a mitigation bank. Examples of objectives for mitigation banking identified by local governments include:

- Use as part of a comprehensive watershed plan that addresses urban development and the need for preservation and restoration of wetlands

- Provide an incentive for economic growth by streamlining the process for providing compensation of unavoidable wetlands impacts

- Provide for restoration of degraded wetlands that otherwise might not be improved because of insufficient funding

- Use as part of a multi-objective strategy to manage stormwater, flooding, water quality, etc.

- Compensate for wetland losses from future local agency projects

Types of Mitigation Banks

Once the objectives for the proposed bank have been established by the local agency, the type of bank to meet the identified objectives must be determined. Local governments can establish a mitigation bank for their individual use or for credit sale as a commercial venture. The bank can be established solely by a public agency or as a joint venture with a private entity (e.g., entrepreneurial business). Mitigation bank types need not be mutually exclusive; for example a commercial mitigation bank may be established through public/private partnerships and still be part of a watershed management plan.

Commercialbanks: A commercial mitigation bank is one in which the credits are sold to a party other than the bank sponsor (banker). The banker sells credits within the established service area to permittees who have approval from the U.S. Army Corps of Engineers (Corps); the agency responsible for issuing wetlands development permits; to compensate for wetland impacts through a mitigation bank.

Sing/e-user: A single-user mitigation bank is established by a local agency to compensate only for wetland losses associated with activities conducted by the agency.

Factors Contributing to Mitigation Bank Success

Conditions for successful bank establishment

Local governments which have successfully established a mitigation bank have identified several conditions that need to be considered in order to successfully meet environmental and/or economic objectives.

- There must be a demand for compensatory mitigation within the local jurisdiction. Demand results from development pressure in a rapidly growing area where impacts to wetlands are expected to occur. The value of development in regions with rapid growth increases the willingness of the public agency or developer to pay for wetland mitigation. Potential bank sponsors should conduct a “needs” analysis to determine the demand for a mitigation bank in a given area. The analysis will show the extent of potential wetland impacts in the region and whether mitigation banking is a viable compensation option. Once demand for a bank is decided upon, the size of the bank can be determined.

- There must be a sufficient supply of available sites for restoration, creation, enhancement, or preservation.[3] The availability of appropriate sites will vary by geographic region. For example in Florida, large tracts of degraded wetlands have been impacted by previous land-use practices and by invasion of exotic plant species. Such large areas are conducive to restoration and enhancement. In some areas, there are mitigation banks where property is in high demand, resulting in high land acquisition costs. In other circumstances, finding an appropriate site may be difficult due to the lack of large wetland expanses. Land that is in public ownership can help lessen land acquisition cost, but may not have favorable physical attributes that would allow for a mitigation bank to be self-sustaining over time.

- Finally, regulatory coordination is important. The local agency needs to provide a prospectus to the Mitigation Banking Review Team (MBRT) established by the local Corps district.[4] The prospectus will serve as the mitigation banking instrument that identifies the objectives and administration of the proposed bank. As pat-t of this coordination process, the local agency should identify the proposed bank site, the geographic service area, wetland types suitable for compensation at the site, the debiting and crediting system, performance standards, monitoring plan, contingency and remedial actions, and provisions for long-term management and maintenance.

♦ Proposing a mitigation bank in the context of a regional plan that integrates the bank into a comprehensive wetland or watershed management strategy may improve the likelihood of acceptance of the prospectus by the MBRT. A watershed management plan can provide greater certainty about the nature and extent of future wetland impacts and identify the most appropriate, environmentally beneficial options for offsetting the anticipated impacts. In this way, the MBRT has a level of assurance that the bank is a part of a broad goal to maintain or gain wetland functions in a given area or watershed.

Site selection criteria

Local agencies need to carefully consider the sites that are identified for potential mitigation banks. Site selection is one of the most important criteria affecting the successful establishment of a mitigation bank. The most significant site selection criteria is the potential that the site can be successfully restored or enhanced in a manner that will provide appropriate compensation for anticipated unavoidable wetlands losses. Selection of such ecologically important or desirable sites can further regulatory acceptance.

As identified in the federal guidance on mitigation banking, mitigation sites should be self-sustaining over time. Sites with naturally occurring hydrology are preferable to sites that require complex hydraulic engineering features that are costly to develop, operate, and maintain. Therefore, sites that can be restored without complex improvements should be the first option when establishing a mitigation bank.

Ideally, site selection would be undertaken in accordance with a watershed management plan under which existing wetlands have been surveyed to determine which sites are the highest priority for protection, the most suited for restoration or enhancement, and the most likely to be impacted by development. Through watershed planning, wetland functions that are lacking in a region can also be used to guide site selection. Additionally, planning at this level can help determine compensation requirements, because anticipated wetland impacts can also be identified. Two federal programs, the Special Area Management Plan (SAMP) and the Advance Identification (ADID) Program, can provide guidance and technical assistance to local sponsoring agencies that meet certain criteria and are interested in establishing a watershed scale planning effort.

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[3] The Federal Mitigation Banking Guidance states that the use of preservation in a mitigation bank may be authorized by the federal agencies when it is demonstrated that the preserved areas contribute to the functions of the restored, created or enhanced aquatic resource.

[4] The Mitigation Banking Review Team is established as consistent with the Federal Mitigation Banking Guidance.

Mitigation bank site selection can also be targeted to address specific environmental objectives. For example, wetlands in several counties in Florida were overrun by exotic vegetation. Mitigation banking provided the funds to improve the wetland habitat through exotic species eradication and revegetation with native plants.

Site selection may also be influenced by a regional demand for mitigation opportunities and the availability of suitable restoration sites. Land acquisition is often cost-prohibitive for local agencies: land ownership, zoning restrictions, and allowable uses also are important factors in determining a mitigation bank site. Important functional characteristics of a potential restoration site include the presence of hydrology, hydric vegetation, and/or hydric soils; size of the site; historic conditions; and the degraded condition of existing wetland (e.g., exotics, fill, compaction, trash). Experts in restoration should be consulted regarding specific wetland requirements and regional wetland attributes prior to site selection.

Funding

The most common funding option used by local governments is the advance-credit sale option addressed in the Federal Mitigation Banking Guidance.With this funding mechanism, advance sale of a percentage of the total credits is allowed after certain criteria have been met by the bank sponsor, such as conservation easement, land acquisition, and/or design plan approval. By selling a limited number of credits in advance, the banker can collect sufficient funds to begin conducting wetland improvements, then sell more credits as they are certified by the regulatory agency. The advance sale of credits, however, involves a degree of risk; for example, problems can arise prior to mitigation bank implementation or completion, leaving the bank sponsor liable for any credits sold.

Local governments have also identified various other strategies for funding the establishment of their mitigation banks. Some of the options include:

- Completing the project in phases so that initial credit sales will provide funding for the remainder of the project
- “Borrowing” money from other local agency funds, then paying it back using money from credit sales
- Using available federal or state grant money for wetland improvement as seed money to establish the banks;[5]
- Partnering with a private company to share the costs
- Using combinations of the above mechanisms

Bank Administration and Operation

Several issues related to bank administration and operation pose a challenge to local governments. The geographic service area, credit ratios, credit valuation, monitoring plans, and long-term maintenance provisions are all issues that must be addressed by the local sponsor and approved by the signatory agencies. Information on these issues can be found in the Federal Mitigation Banking Guidance mentioned earlier, as well as in any existing state guidance. A partnership with a private entity that has experience in mitigation banking is one alternative for addressing bank administration and operation challenges.

The geographic service area for the mitigation bank should be established and presented in the mitigation banking planning document. The service area is the area in which credits from a mitigation bank can be used to compensate for unavoidable wetland losses. This area can be a watershed or a political boundary, such as a county or municipality.

The number of credits produced by a mitigation bank are generally determined by two factors, (1) the number of acres restored, created, enhanced, or, in exceptional circumstances, preserved, and (2) a quantified evaluation of the

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[5] EPA has also identified the State Revolving Fund (SRF) as another potential source for funding the establishment of mitigation banks, subject to approval under each State’s SRF regulations.

functional value of the wetlands in the bank. As a general matter, the greater the wetland improvement, the more credits generated. For example, more credits may be associated with restoration and fewer credits associated with enhancement. The second factor involves a functional assessment of the improved or created wetland, and a method for converting the functional units to credits.

To determine the appropriate compensation requirements for wetland losses, a mitigation ratio must be developed. This ratio can be based on lost wetland function and area, the rarity of the affected wetland, and the wetland replacement kind and function. The ratio will determine the number of credits required from the bank to replace the impacted aquatic resource. Generally, the mitigation ratio is greater than or equal to one; i.e., at least one credit (acre of restored, enhanced, or created wetlands) required to replace one acre of lost wetland resource.

As a general matter, the bank sponsor monitors the bank for a period of time (e.g., five years) to determine whether the bank is functioning at the level required by a previously determined set of performance standards established in the banking instrument. After the performance standards are met, the local agency may choose to transfer the mitigation bank to another entity (e.g., land trust) for the long-term maintenance and monitoring. An agency can also use volunteer labor to offset costs of monitoring and maintenance and to improve public awareness and citizen stewardship for the project. Among the local bank projects reviewed by EPA in the survey, local sponsors were usually responsible/liable for the performance of the mitigation site from the beginning, or after an established period of time if the project was a joint-venture.

Financial assurances for long-term maintenance and contingency plans for the bank most often take the form of additional fees added onto the cost of a credit, with a fixed amount from the sale of each credit put into an escrow account. The local agency then draws from the account for necessary maintenance expenditures. In some cases, completed banks become part of a park system or are turned over to a public agency for long-term management.

Mitigation Bank Approaches with Case-Study Examples

The following case-studies are examples of the different types of mitigation banks that can be established by a local agency, and highlight specific issues that are of concern to local governments. The banks discussed in the case-studies are not mutually exclusive, in that a given bank may fit into more than one “bank type” category.

Mitigation Banking in the Context of a Watershed or Wet/and Management Plan

Local governments can use a watershed or wetland management plan as a means of addressing economic development and environmental concerns. An important aspect of such a plan involves compiling an inventory of existing wetlands in order to determine both coverage area and functions provided. This information can then be used to protect important resources, establish areas suitable for development, and determine the best sites for restoration. Mitigation banking is, therefore, a tool that can be integrated into a watershed plan to help meet resource management objectives.

Advantages of mitigation banking in the context of a watershed management plan are as follows:

- Sites to be restored and critical sites to be preserved are already identified in the plan
- Market demand for compensatory mitigation can be identified
- The extent and nature of potential impacts have been determined
- Likelihood of restoration project success is improved
- Uncertainty for regulatory agencies is lowered
- Multiple objectives can be attained

- Environmental benefits are maximize

West Eugene Mitigation Banking Program

Overview: The Eugene Wetland Mitigation Bank Program (Bank) was established in 1995. The program is operated by the City of Eugene, Oregon, under a separate fund within the City's financial structure. The goal of the Bank is to provide a mechanism to fund wetland mitigation projects, carry out the West Eugene Wetlands Plan (Plan) adopted in 1992, and meet other community needs. This program is being conducted in cooperation with the City's wetland partners (the U.S. Bureau of Land Management [BLM] and the Nature Conservancy [TNC]).[6] The objectives that the City seeks to accomplish with the mitigation banking program include:

- Creating credits in advance of wetland losses
- Meeting the mitigation needs of the community of Eugene
- Achieving community objectives, such as increased flood storage capacity, enhanced water quality, improved wildlife habitat, and establishment of education and recreation opportunities
- Targeting areas with high prospects for restoration success such as historic wetlands, disturbed agricultural wetlands, and areas adjacent to waterways
- Communicating the banking program's value to the community
- Operating the bank as part of a national model wetland program in cooperation with the wetland partners
- Establishing a permitting process familiar to businesses, environmental interests, and regulatory agencies

Funding for identifying wetland areas for the bank was provided through EPA's Advanced Identification (ADID) program. The West Eugene Wetlands Plan integrates wetlands protection and community development needs by identifying areas best suited for wetland preservation and areas with development potential. Thirteen hundred acres of wetlands were identified within the plan area, with more than 1,000 acres designated for protection or restoration and approximately 300 acres of lower value wetland designated as suitable for future fill and development. The Plan calls for the establishment of a mitigation banking program to compensate for unavoidable losses of wetlands through restoration and enhancement in conjunction with protection of important wetland resources.

All mitigation bank projects will be located within the Long Tom River watershed. Seven projects were initially constructed for a total of 56 acres. Three additional projects totaling 60 acres were in planning at the time of the EPA survey.

In this program, mitigation bank credits can be established in three ways

1. The City or its partners may undertake wetland mitigation work, then seek certification of credits by the Corps and Oregon Division of State Lands (DSL). The City provides documentation on a site prior to the mitigation work and after completing improvements to demonstrate an increase in wetland values.
2. The City may create more credits than are needed to compensate for permitted wetland losses as part of concurrent or advance mitigation work. If the Corps and DSL certify the excess credits, they will be added to the Mitigation Banking Program's ledger for sale.
3. Uncertified credits may be sold in order to fund initial mitigation work, which are later certified by the Corps and DSL when the initial hydrological and vegetative work is completed.

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[6] City of Eugene, Public Works Department. 1997. West Eugene Wetland Mitigation Bank, Annual Report 1996.

The City Stormwater Fund provided money for acquisition of site properties. Additional capital for the projects came from the sale of uncertified credits. No uncertified credit can be sold unless the Corps and DSL have approved a mitigation plan.

As the bank sponsor, the City is responsible for monitoring and maintaining the bank sites. Monitoring is required for a minimum of five years and the sites will be inspected by the Corps and DSL on an annual basis. Monitoring goals are determined on a site-by-site basis. Maintenance will be conducted to ensure that the wetland functions and values are fully established and functioning. If the site is not meeting the performance criteria, corrective measures will be taken. Funding for these tasks is included in the credit price. At least an additional 20% will be added to the estimated credit cost and set aside to be used to monitor, maintain and, where necessary, conduct remedial measures.

Single-user Mitigation Bank

Local governments can establish a single-user bank. In this case, the local government initiates the bank, creates the credits, and is the principal credit user. Local sponsors with long-range project plans that involve potential impacts to wetland areas may establish a mitigation bank or banking program in anticipation of the need for compensatory mitigation. For example, a public works department with road expansion plans may know in advance that there will be unavoidable impacts and provide the funds necessary to initiate a bank in anticipation of the project.

An advantage of a single-user bank is that long-term planning provides advance knowledge of potential wetland losses associated with future projects. This reduces the uncertainty surrounding the demand for the bank and eventual funding. Funding may be available to initiate the bank based on the predicted future use.

Snohomish County Airport Mitigation Banking Program

Overview. The Snohomish County Airport (SCA) needed to address the multiple objectives of their 20-year Master Plan, the aviation needs of the airport, the economic growth of the region, and environmental protection. The Master Plan identified three development/construction projects that will occur over five years, each with anticipated wetland impacts. The objectives that the SCA seeks to accomplish through the banking program include:

- Creating a mitigation alternative for projected airport development
- Replacing or augmenting wetland functions in the watershed
- Replacing habitats that will potentially be lost, including open-water habitat that cannot be created on-site
- Creating recreational and educational opportunities

The SCA analyzed the three watersheds containing the project areas to determine missing wetland functions and values. Potentially impacted wetlands were then characterized according to acreage, wetland category, and function. Based on these analyses, two mitigation banks were designed to replace the wetland functions that would be lost by the airport projects. The SCA banking program creates a "reserve" of mitigation that accommodates Master Plan impacts for approximately seven years.[7]

Mitigation banking was an effective alternative for the SCA since the Federal Aviation Administration (FAA) prohibits the creation of bird attracting habitat within 10,000 feet of a runway. In this circumstance, on-site mitigation was determined not to be a viable alternative as it would attract waterfowl and migratory birds. The SCA created or enhanced a total of 32 acres and preserved an additional 23 acres.

Following a format developed by the Washington State Department of Transportation, the SCA Memorandum of Agreement (MOA) was established. The MOA describes the procedures for selecting, managing, monitoring, and

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[7] Snohomish County Airport. 1997. Snohomish County Airport MOA/IM Executive Summary.

protecting mitigation banks. Additionally, an Implementation Manual was created by the SCA that presents agency recommendations for approval of the two specific bank sites. A technical oversight committee reviewed and advised changes to the MOA, and provides input for credit evaluation and ratio development.

Construction is nearly complete at both sites. One site has a nonprofit organization associated with it called the *Friends of Narbeck Wetland Sanctuary* that is working to promote citizen stewardship, protection of wildlife and wildlife habitat, native plant propagation, and environmental research.

Primary funding for the mitigation banks came from airport revenues. In addition, some funds were provided from the FAA, since the program will be used to mitigate for projects required by FAA safety regulations.

The SCA will be responsible for one of the sites in perpetuity. The other site will be donated to the City of Everett, Washington, Parks Department after all of the credits have been used. Monitoring will be conducted for five years in the emergent wetland and ten years in the forested wetland. Both sites have been placed in a conservation easement and a contingency plan will be executed if performance criteria are not met.

Public/Private Joint Venture

Public/private joint ventures can facilitate mitigation-bankestablishment by providing investment capital and technical expertise. Mitigation banking is a complex process involving aspects of design, engineering, regulation, project management, biology, ecology, marketing, and long-term management. Because of this, a mitigation banking joint venture may be established to share the responsibilities and costs. A local agency role may be bank sponsor, bank creator, land owner, long-term manager, or all four. The private entity may conduct only the technical work, but can also assume any of the aforementioned roles. The EPA survey found that the local agencies partnered in joint ventures were most likely to provide the land for the mitigation bank and the private entity would provide funds and/or technical expertise.

City of Pembroke Pines and Florida Wetlandsbank, Inc.

Overview: In 1992, the City of Pembroke Pines in Broward County, Florida, entered into a partnership agreement with Florida Wetlandsbank, Incorporated to restore a heavily degraded site that was already overrun by exotic species and becoming further deteriorated by all-terrain vehicle use and illegal trash disposal. The City did not have the resources necessary to restore the site or to establish a mitigation bank. Concurrently, development pressures in the area were creating a demand for an effective mitigation alternative.[8] Florida Wetlandsbank agreed to design and construct a wetland system by eradicating the exotics and replacing them with a mixture of 10 typical Everglade habitats including cypress stands, emergent marshes, tree islands, and sawgrass prairie. Florida Wetlandsbank also provided the management for the bank, selling the first credits in 1994. In 1997, restoration was near completion, with 396 credits sold. The objectives for the Florida Wetlandsbank (the name of the mitigation bank) are to:

- Provide a mitigation alternative for the rapidly urbanizing City of Pembroke Pines
- Provide mitigation at a large site with high potential for ecological success
- Restore native wetland ecosystems in an area that was degraded and infested with exotic species

The mitigation bank provided a number of economic and environmental benefits, including the following.

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[8] Paul Wattles, Assistant City Manager, City of Pembroke Pines, Florida. Personal communication, March 23, 1998.

- The project provided revenue for the City through the collection of franchise fees per acre (paid by Florida Wetlandsbank, Incorporated after credits were sold).
- Developers used the credits as quickly as they became available.
- The City plans to open part of the area as a park and offer public access and passive recreation opportunities.
- To date, the site is ecologically successful, with little reinfestation of exotic plants.
- Florida Wetlandsbank, Incorporated profited from the sale of credits.

The construction is completed and all credits sold for the original 350-acre site. An additional 100 acres has been added to the site with construction nearly completed and credit sales pending. The service area for the mitigation bank was kept at the county level rather than the basin level, which incorporates three counties. The County determined that mitigation for wetland losses should remain within the county.[9] The number of credits available in the mitigation bank were determined using a modified Wetland Rapid Assessment Procedure (WRAP).

Florida Wetlandsbank, Incorporated provided the capital for initiating the bank. Pre-project sale of credits allowed restoration work to begin. A trust fund was established to provide for the long-term maintenance of the site, with $1,000 per credit contributed to the fund.

Site monitoring will be conducted by Florida Wetlandsbank, Incorporated from the time that construction is completed for five years. Quarterly monitoring reports are required by the SFWMD. These reports contain information regarding the banks performance criteria. A performance bond was placed with the SFWMD for each stage of construction. The bond will be used in the event that any of the performance criteria are not met. Once the performance criteria for the site are met, the money will be released to Florida Wetlandsbank.

Commercial Mitigation Banking

A local government can establish a commercial mitigation bank that sells credits to anyone who meets the requirements to use the bank for compensatory mitigation. The bank discussed here was established on public land, solely by public agencies, with credits for sale to the public. Optimally, a public commercial mitigation bank is part of a larger watershed plan.

A major advantage of public commercial banks is that they are in public ownership, which can better provide long-term management, and the funds generated from the bank can be used to further improve public resources. The disadvantage is that the up-front capital investment can be difficult for public agencies with limited availability of funds

DuPage County, Illinois

Overview DuPage County is a highly urbanized area located west of Chicago. Land development has negatively impacted the natural drainage system of the area by eliminating naturally occurring storage, reducing stormwater infiltration, and increasing the velocity and quantity of runoff. In response, the DuPage County Stormwater Management Plan (Management Plan) was developed in 1989, to reduce the potential for recurrent and increasing flood damage and to reduce further environmental degradation associated with development. The ecological assessment conducted during development of the Management Plan found that wetlands represented a significant portion of the natural watershed

[9] Desmond Duke, Project Administrator, Florida Wetlandsbank. Personal communication, June 19, 1998.

storage in the county, and are essential for adequate stormwater retention, conveyance, sediment control, and water quality enhancement."

Individual watershed plans, within the larger DuPage County management plan, were developed to identify wetlands for protection, enhancement, and restoration. The County attempts to establish mitigation banks in the four main watersheds within the County. The service area for each bank will be the watershed in which the bank is located. The County also established an ordinance for stormwater management that requires developers whose development proposals will affect the function and values of wetlands to consider mitigation banking as an alternative to compensatory on-site mitigation. The objectives of the DuPage County commercial mitigation banking program are to:

- Manage and mitigate the effects of urbanization on stormwater drainage
- Enhance the quality, quantity, and availability of surface and groundwater resources and prevent further degradation
- Preserve and enhance existing wetlands, aquatic, and riparian environments
- Encourage restoration of degraded areas

Any investment in a bank must be at least equal to the cost of planning, acquiring lands, constructing, and operating and maintaining mitigated wetlands of equivalent or greater functional value than those lost to development.

The land for the bank sites was in public ownership. Funding for establishing the bank and initial project work came from an advanced credit sale. One-third of the credits were allowed for sale prior to work beginning at the site. One site, Winfield Creek, was in the process of selling credits for project initiation when public opposition to the site halted the project. The County is now in the process of finding another site but, in the interim, is liable for the credits sold.

The County has five banks that have been approved by the agencies and are in various stages of implementation. The oldest project, Cricket Creek, is in year two and, to date, is exhibiting successful hydrologic and vegetation conditions.

Conclusion

The use of mitigation banking by local governments can be an effective tool to restore and protect their community's valuable wetlands resources. The case-studies presented provide local governments with different mitigation banking strategies that could be used to address the needs of their community. As demonstrated in the case-studies, the establishment of sound objectives and goals by the local agency will help determine the type of mitigation bank that will best meet the local needs. In addition, there are several conditions that local governments must evaluate and consider for successful bank implementation, including (1) a demand for compensatory mitigation, (2) a sufficient supply of suitable sites for the bank, and (3) opportunities for working in partnership with the federal and state regulatory and resource agencies.

Mitigation banks that are established by local governments can address more than just the need for compensatory mitigation. Wetlands mitigation banks can achieve additional community needs by increasing local flood storage capacity, improving wildlife habitat, and providing educational and recreational benefits while restoring and enhancing important wetland resources.

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[10] DuPage County Stormwater Management Committee. 1989. *DuPage County Stormwater Management Plan.* DuPage County, Illinois.

Massachusetts Stormwater Management Policy/Regulations: Development, Implementation, and Refinement

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Abstract

In March of 1996, the Massachusetts Department of Environmental Protection, in conjunction with the Massachusetts Office of Coastal Zone Management, released the Draft Version of the State's Stormwater Management Policy. The Policy includes nine specific Stormwater Performance Standards, which are to be met to achieve compliance. The Policy presented in two volumes: Volume One, the *Stormwater Policy Handbook,* which contains a description of the policy, its implementation, and descriptions of the nine individual stormwater management standards, and Volume Two, the *Stormwater Technical Handbook,* which contains more detailed information on Best Management Practices (BMPs), for stormwater management (i.e., detention basins, swales, etc.).

The policy is the result of three years of work by a Stormwater Advisory Committee that included representatives from regulatory offices (EPA, Department of Fisheries and Wildlife, Natural Resources Conservation Service, etc.), engineers and developers from the private sector, the highway department, and representatives of local conservation commissions. The Policy is to be implemented as an amendment to the existing Massachusetts Wetlands Protection Act, which is administered at the local level by local Conservation Commissions.

The nine performance standards are the key components of the policy. General descriptions of the standards include the following:

1. No new stormwater conveyances may discharge untreated stormwater directly to, or cause erosion in wetlands or waters of the Commonwealth.

2. Post-development peak discharge rates may not exceed pre-development rates.

3. Maximize recharge to groundwater: post-development must be similar to pre-development conditions.

4. Remove 80% of average annual load-post development of Total Suspended Solids (TSS).

5. Use specific BMPs for discharges from areas with higher potential pollutant loads; untreated infiltration prohibited.

6. Use specific BMPs for discharges to critical areas.

7. Redevelopment projects should not meet performance standards to the maximum extent practicable and at a minimum, improve existing conditions.

8. Erosion and sedimentation controls are required during construction.

9. Operation and Maintenance Plan for Stormwater Management required.

The Policy was introduced in March of 1996 for testing its effectiveness. Two Phases of training were provided over a two-year period across the state. The first phase focused on introducing the Policy and the second phase focused on detailed Engineering Companies, and local DPWs and planning departments.

Introduction

In March of 1997, the Massachusetts Department of Environmental Protection (MADEP), in conjunction with the Massachusetts Office of Coastal Zone Management (CZM), released a draft version of the state's Stormwater Management Policy (herein referred to as the "Policy"). Prior to the development of this policy, the control of peak stormwater discharges from development sites to prevent flooding and erosion problems was a fairly standard requirement across the country; and was well-implemented in Massachusetts. However, there were no state-level requirements for stormwater quality treatment, maintaining groundwater recharge processes, or maintaining stormwater treatment systems. The Policy was developed to provide standard minimum requirements for stormwater management that could be consistently implemented on development projects.

The Stormwater Management Policy is currently an amendment to the Wetlands Protection Act which is only applicable when a project proposes work within the boundary, or buffer zone, of a Wetland Resource Area. Hence, the Policy is not applicable to all developmental projects.

While the regulatory implementation of the Policy is through local Conservation Commissions, under the State's Wetlands Protection *Act,* the performance standards and design guidelines that define the Policy were developed for use by a larger audience. Development teams (typically the proponent and their engineers, architects, and planners) and the various reviewing agencies (Conservation Commissions, Planning Boards, DPWs, etc.) were expected to be users of the Policy. The goal was to provide guidance to ensure that negative impacts from stormwater runoff generated as a result of urban and suburban development would be minimized without placing an unjustifiable economic burden on developers for new projects, or preventing redevelopment of existing sites.

The Policy includes nine specific Stormwater Performance Standards for which compliance must be achieved on development projects. Included in these standards is a requirement to provide groundwater recharge, requirements for ensuring proper stormwater treatment prior to discharge to waters of the state, and provisions for waiving certain requirements if deemed infeasible for redevelopment projects. The Policy has been distributed as an Interim Draft to allow for refinements prior to its final promulgation as state regulations. In order to fully gage its effectiveness, however, the Interim Policy has been distributed and implemented as if the regulations were final.

The Policy is presented in two handbooks: Volumes One and Two. Volume One, the *Stormwater Policy Handbook,* contains a description of the policy, its implementation, and detailed definitions of the nine individual stormwater management standards. Volume Two, the *Stormwater Technical Handbook,* contains detailed information on Best Management Practices (BMPs), with guidelines for the design of standard stormwater management structures (such as detention basins and water quality swales).

Development

The Policy is a result of three years of work by a State Stormwater Advisory Committee. In addition to leaders from MADEP and CZM, this Committee included representatives from such regulatory offices as USEPA, Department of Fisheries and Wildlife, and the Natural Resources Conservation Service. Also on the committee were engineers and developers from the private sector (including the author) and representatives from the Massachusetts Highway Department and local Conservation Commissions.

The goal of the Committee was to provide a cohesive set of performance standards that addressed key issues associated with stormwater runoff control. The Policy was developed in such a manner that it provides adequate accompanying guidelines and recommendations, to allow for consistent implementation, while still allowing for flexibility in site-specific designs. Given the widely varying goals and perspectives of Committee members, the Policy published in 1997 was a result of group consensus and compromise.

The Committee was divided into two sub-committees, the Policy group, and the Technical sub-committee. The Policy group was tasked with developing the process for legal implementation and the Technical Committee was responsible for developing the specific technical requirements of the Stormwater Management Policy.

Some of the performance standards introduced completely new requirements for development projects and required detailed evaluation and discussion during the development stages. Some of the key issues that generated substantial debate include the following:

- ***Recharge:*** The loss of recharge to groundwater systems, which provide drinking water supplies and generate baseflow to streams and rivers, was a state-wide problem. A mechanism for requiring the maintenance of recharge after development was considered a high priority. The biggest issue relative to this requirement was: How much annual recharge should be required?

- ***Water Quality Treatment Volume:*** The quality and quantity of stormwater runoff from paved and unpaved areas can vary greatly. It was determined by the Committee that runoff from impervious areas was the highest concern and should require treatment. The largest decision relative to this concern was: What volume of stormwater runoff should be treated for water quality? Should it include runoff from both pervious and impervious areas?

- Critical Areas: The Committee felt that certain sensitive environmental areas should have the maximum practicable protection. Under the Massachusetts Stormwater Management Policy, "Critical areas" are defined as; shellfish growing areas, public swimming beaches, cold water fisheries, recharge areas for public water supplies and designated Outstanding Resource Waters (ORWs). ORWs are further defined to include surface drinking water supplies, certified vernal pools, and state designated Areas of Critical Environmental Concern (ACECs). The issue here was how to ensure that these areas are provided adequate protection and how to define what adequate protection is.

- ***Exemptions:*** Some Committee members expressed concern that stormwater management requirements may be too costly for small residential projects, or may be a deterrent for initiating redevelopment projects. The issue was what, if any, projects should be exempt from any or all of the standards?

- ***Operation/Maintenance:*** Maintenance of stormwater management practices is critical for their effectiveness. It is often difficult, if not impossible, to ensure that the operation and maintenance of BMPs will occur as necessary. The issue was: How can the necessary maintenance of BMPs implemented on the project be ensured?

A brief summary of the decisions on these key issues is as follows:

- ***Recharge:*** Annual recharge processes are permanently changed by the introduction of impervious areas to a site. In order to minimize this impact, it was agreed that the existing annual recharge should be determined and post-development annual recharge should maintain this to the maximum extent practicable. A preliminary methodology for determining existing recharge on the site was provided in the Draft Policy.

- Water Quality Treatment Volume:

  - For discharges to critical environmental areas (defined in the Policy), the volume of stormwater runoff to be treated for water quality control is defined as 1 .O inch of runoff times the total impervious area of the post-development project site.

  - For all other discharges, the volume to be treated is calculated as 0.5 inches of runoff times the total impervious area of the post-development project site.

  These volumes represent total runoff from the smaller, more frequent storms that occur annually, and the initial volumes of runoff from larger more infrequent storm events. The goal behind this decision was to fully treat the runoff from the majority of the storm events occurring annually, without approaching values where treatment system sizes would result in increasing costs with decreasing additional benefit.

  - ***Critical Areas:*** It was decided, as stated above, that 1 .O inch of runoff (as opposed to 0.5 inch) must be treated for water quality if the discharge is to a Critical Resource Area. Also, specific approved BMPs are recommended for use in particular critical areas. In addition, it was decided that spill prevention/containment methods must be included in the Stormwater Management System design.

- Specific cases were provided exemption from the Policy, including: single family house projects, residential subdivisions with four or fewer lots that do not discharge to critical areas, and emergency repairs to highway/roadways or their drainage systems. However, none of these projects are exempt from the standard requiring sedimentation and erosion control requirements during construction activities.

  While redevelopment projects are not exempt, a redevelopment project may comply to the maximum extent possible if it can be proven that it is not practicable for the project to achieve full compliance.

- ***Operation/Maintenance:*** All non-exempt projects require the development of a Stormwater Management System Operation and Maintenance Plan (O&M Plan). As defined in the Policy, the O&M Plan must contain the: names of the Stormwater Management System(s) owner and the person(s) responsible for implementing the O&M Plan, a schedule for inspection and maintenance, and a description of maintenance activities to be performed. Recommendations for specific maintenance practices and schedules are included in the Policy.

Stormwater Performance Standards

The nine Stormwater Performance Standards most accurately describe the key components of the policy that came out of the committee deliberations following resolution of the issues described above. The goal of the standards is to protect groundwater, surface water, and wetland resources from the impacts of stormwater runoff generated as a result of development and redevelopment projects. General descriptions of the standards are provided as follows:

1. No new stormwater conveyances may discharge untreated stormwater directly to, or cause erosion in wetlands or waters of the Commonwealth.

2. Post-development peak discharge rates must not exceed predevelopment conditions for the 2-year and 1 O-year storm events under all conditions. The 100-year event must be analyzed to determine impacts and must be controlled if necessary.

3. Loss of annual recharge to groundwater should be minimized through the use of infiltration measures, to the maximum extent practicable. The recharge "requirement" which is to mimic existing annual recharge on sites to the maximum extent practical, has not been changed. However, a design methodology for estimating existing annual recharge at a site, and for designing recharge systems has been developed. The methodology uses soil classifications, soil gradation analyses and specific Massachusetts regional rainfall data as data inputs.

4. Stormwater management systems must be designed to remove 80% of the average annual (post development) load of total suspended solids (TSS). It is presumed that this standard is met when; (a) suitable nonstructural practices for source control and pollution prevention are implemented; (b) stormwater management BMPs are sized to capture the prescribed runoff volume; and (c) stormwater management BMPs are maintained and designed as specified in Volume Two. The Policy provides estimates of the percent TSS removal for individual BMPs when designed in accordance with the specified guidelines. Water quality treatment volume is 0.5 inches of runoff from impervious areas (1 .O inch if discharge is to critical environmental area).

5. Stormwater discharges from areas that are defined as having "higher potential pollutant loads" (as defined in the Policy) require specific stormwater BMPs. Infiltration of stormwater from these areas without pretreatment is prohibited.

6. Specific BMPs must be used for discharges to critical areas and the water quality treatment volume is 1 .O inch of runoff.

7. Redevelopment projects must meet the performance standards to the maximum extent practicable. It must be clearly stated why full compliance cannot be achieved and such projects must, at a minimum, improve existing conditions.

8. Erosion and sedimentation controls are required during construction.

9. An Operation and Maintenance Plan (O&M Plan) for Stormwater Management is required.

A detailed explanation of each of these Standards is available in Volume One, the Stormwater Policy Handbook.

Implementation

In order to test its effectiveness and identify potential problems, the Policy was introduced in March of 1997, prior to the promulgation of regulations. Copies of Volumes One and Two were distributed to each Conservation Commission office in the state, and to other relevant regulatory agencies. Two phases of training were provided across the state over a two-year period: first to introduce the Policy, and then to focus on detailed case studies and implementation issues. Training was made available to regulatory agencies, Conservation Commissions, local DPWs, planning departments, and engineering companies. During the training sessions, the largest turnout was from Conservation Commission representatives and engineering/consulting firms, with minimal attendance by the other groups invited.

At each of the training sessions, questions from the audience on the Policy were solicited and a list of most Frequently Asked Questions (FAQs) was developed. The FAQs provided an excellent basis for outlining where additional information and/or clarification was needed. Based on the number of recurring questions, the Committee decided to prepare a survey to solicit feedback from potential policy users. The survey was comprised of 23 questions for characterizing the respondent, determining the usefulness and ease of implementation of the Policy, identifying particular problems in understanding or implementing performance standards, and determining what type of BMPs were currently being implemented.

The survey was not designed to be a statistically valid data set, but rather to gain a practical working knowledge of what aspects of the Policy and/or its method of implementation needed to be refined. While this was generally evident from the FAQs, the survey further substantiated the specific areas where additional work was necessary. Some key findings from the 118 respondents to the survey were as follows:

- The overall sense of the Stormwater Performance Standards was that the Stormwater Policy implementation was good (63%) and that they consider the Stormwater Handbook to be a "useful resource for designing and reviewing systems (77%).

- In response to the standards, respondents were generally comfortable implementing peak discharge controls and sedimentation and erosion controls. This was not surprising since these were existing requirements in most municipalities that needed to be achieved for most development projects.

- Not surprisingly, new requirements for groundwater discharge, treatment of stormwater runoff water, and the preparation of stormwater Management O&M Plans were the standards for which additional clarification and technical support were most requested.

Feedback

The Draft Policy was issued prior to formal promulgation so that one to two years of interim implementation could be used for refinement. The FAQs, user survey, and ongoing feedback from the public defined those areas where refinements were especially necessary, including the following:

Standard No. 3 ***Recharge:*** The recharge requirement clearly created the most confusion, and required additional technical support. The original brief description included in Volume One was not suff icient for engineers or reviewers to prepare a comprehensive program for achieving the annual recharge requirement.

As a result, the technical sub-committee has focused on providing a more detailed definition of the recharge requirement and appointed a group to develop a design methodology for achieving compliance with this standard. The group has developed a methodology using soil groups and soils analysis and actual rainfall data to determine the existing annual recharge on project sites. Methodology for designing a recharge system to provide post-development recharge that best mimics pre-development conditions is being developed. This technical is currently in the final stages of development and is expected to be completed and distributed prior to December 1999.

Standard 4 *- 80% TSS* ***Removal:*** The Total Suspended Solids (TSS) removal requirement was not developed with the goal of removing only the TSS loads in stormwater runoff. Rather, it was considered an indicator parameter, whereby if 80% of the TSS is removed, a large portion of the additional pollutants carried in stormwater is also removed. This relationship does not hold true, however, if the proponent chooses to use only mechanical methods where settling of fines, assimilation of nutrients, or other biological processes that increase pollutant removal do not occur. For instance, a vegetated infiltrating swale, or wet pond, that is designed to provide substantial stormwatervelocity reductions may greatly increase fine sediment removal and may also provide nutrient uptake in addition to gross TSS removal. Astructure that removes solids only, and does not allow for detention or contact with plants or potential filtering areas does not comply with the goal/intent of the TSS removal standard.

In addition, users were having difficulty calculating TSS removals when numerous BMPs were to be used in a series. The specific percent removal rates provided in Volume One of the Policy are not additive and, as such, must be calculated as percents of the pollutant load that they receive.

In response to these issues, further definition of the goal of the TSS removal requirement and recommended practices for achieving the goal are being developed. A spreadsheet has been developed, which can be easily filled out by hand, to assist in calculating the percent TSS removal for a project based on the BMPs implemented.

Standard 9 - Operation and Maintenance: This standard has consistently raised the most concern relative to cost and implementation. Common questions were as follows:

- Who will pay for ongoing operation and maintenance of stormwater BMPs if it is not the town?
- How will the town fund the O&M requirements if they assume responsibility?
- What long-term mechanism is there to ensure that maintenance will be completed?
- What is the frequency of maintenance required for specific BMPs?

While these questions are difficult to answer, for a specific site or on a statewide basis, in terms of required maintenance, the Committee has responded by preparing operation and maintenance checklists, which may be used by the operator/owner. These checklists may be submitted to the local Conservation Commissions on an annual basis, if deemed necessary.

Specific maintenance practices and suggested frequencies have also been prepared and are currently being updated, as new information becomes available. It has also been noted that "one size does not fit all" in terms of required maintenance. For instance, an infrequently used residential guest parking area clearly does not warrant the same frequency of street sweeping as a commercial mall parking lot.

The question of financing stormwater management system operation and maintenance activities is also a site- and location-specific issue. The development of stormwater utilities and management districts is ever increasing and may be the option that some communities choose. The promulgation of the Policy as regulations will require the project proponent and/or towns and municipalities to develop a plan for ensuring O&M implementation. There are a variety of ways this may be achieved. Resolution may be somewhat facilitated in larger municipalities and/or USEPA-designated urban areas that must comply with the upcoming final USEPA NPDES Phase II Stormwater Regulations.

Summary

The development of the Massachusetts Stormwater Policy, which includes nine performance standards, was an integrated effort between state and local regulators, policy makers, engineers, developers, and the general public. The group effort and the implementation of the Policy as a Draft, to which refinements could and have been made, have contributed to the usefulness of the standards. While the development and implementation of the standards are still in the early stages, the Policy provides definitive goals for achieving stormwater water quality and quantity control, and addresses annual recharge on development sites. Until the development of these standards, there was no requirement to maximize groundwater recharge on sites or to mandate the development of the stormwater O&M Plan (unless required under other regulatory programs). These advances will provide an overall benefit to the natural resources of the Commonwealth of Massachusetts. The Stormwater Management Policy Volumes I and II may be obtained off the Internet or by request from:

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Implementation of Michigan's Voluntary Stormwater Permit-a Community Perspective

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Introduction

The Rouge River National Wet Weather Demonstration Project (Rouge Project) has made significant progress in restoring beneficial uses to a large, urban waterway using a holistic, "bottom up" watershed approach. This project was initiated in 1992, by the Wayne County (Michigan) Department of the Environment. The purpose of this document is to present a summary of the activities and progress of the Rouge Project; discuss the watershed approach being utilized in the Rouge Project, including the use of a general storm water permit; and summarize a community perspective on this entire effort.

Rouge Project Background and Summary of Progress to Date

The Rouge River National Wet Weather Demonstration Project is a watershed-based effort, substantially sponsored by the U.S. Environmental Protection Agency (USEPA), to manage wet weather pollution to the Rouge River, a tributary to the Detroit River in southeast Michigan (See Figure 1). The Rouge River Watershed is largely urbanized, spans approximately 438 square miles, and is home to over 1.5 million people in 48 communities in 3 counties. The Rouge River has been designated by the international Joint Commission as a significant source of pollution to the Great Lakes system.

The early focus of the Rouge Project was the control of CSOs in the older urban core portion of the downstream areas of the watershed. As a finite number of point source CSO discharges could be identified, and responsibility for each defined, the traditional regulatory approach of issuing National Pollutant Discharge Elimination System (NPDES) permits mandating corrective action worked relatively well. Additional monitoring of the river showed, however, that other sources of pollution needed to be controlled before full restoration of the river would be achieved throughout the watershed. These other sources of pollution include storm water runoff, interflow from abandoned dumps, discharges from illicit connections, discharges from failed on-site septic systems, and resuspension of contaminated sediment.

The Rouge Project is designed to identify the most efficient and cost-effective controls of wet weather pollution, while assuring maximum use of watershed resources. A great deal has been accomplished in these efforts. The following summarizes some of those accomplishments, focusing on CSO controls first. Approximately 50% of the watershed is served by separate sewer systems, with an additional 20% served by combined sewers (157 overflow points), and the

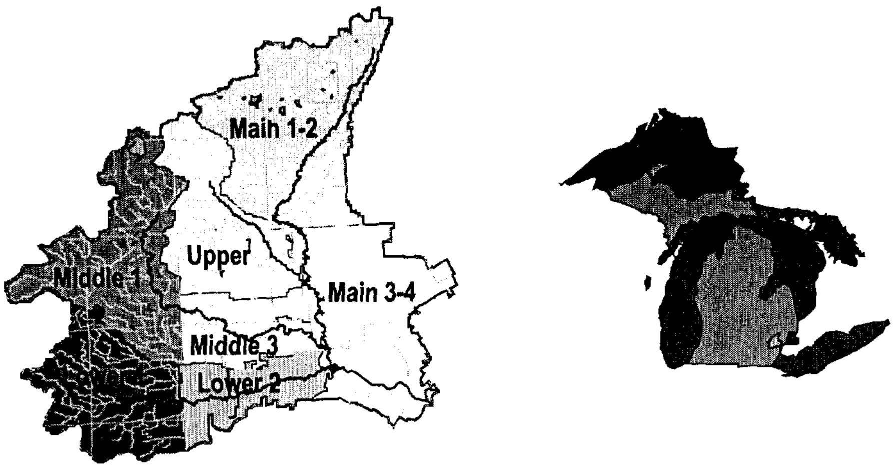

Figure 1. Rouge Subwatersheds & Location of Rouge Watershed in Michigan.

remaining area served by on-site sewage disposal systems. CSO controls are being implemented in phases. Under the first phase, six communities have separated their sewers and eight communities have constructed or are constructing 10 retention treatment basins. Each of these basins is sized for different design storms and several employ innovative technologies. A two-year evaluation study of the CSO control basins began on June 1, 1997. The results from the evaluation study, coupled with efforts to control storm water and other pollution sources in the watershed, will provide the basis for the second phase CSO control program for the remaining CSO sources in the watershed. The information gained from the evaluation of design storms and control technologies will be useful to others nationwide to determine cost-effective CSO controls to meet water quality standards.

The Rouge Project is also evaluating innovative stormwatercontrol and watershed management technologies. Twenty-five different communities and agencies throughout the watershed are implementing over 100 pilot projects. Categories of pilot management projects currently underway include wetlands creation and restoration; structural storm water practices, such as grassed swales and detention ponds; erosion controls; stream bank stabilization; and habitat restoration, to name a few.

The Rouge Project also discovered that illicit connections and failing septic systems are major sources of pollution problems in the Detroit urban area. Creative ways to remediate these sources of pollution have been initiated.

A suite of computer models has been developed by the Rouge Project. These models simulate the water quality and quantity response of the Rouge River during wet weather events for existing and future conditions, and under various CSO and stormwater runoff management alternatives. This effort has resulted in a very useful public communication tool on water quality indices tied to actions needed to restore the Rouge River. A comprehensive geographic information system (GIS) and relational databases were designed and implemented to manage the wealth of data collected under the Project. In addition, a special data exploration tool, DataView, was developed to support routine analyses of large time-series data sets. DataView is user-friendly and readily transferable to other locations. Related to DataView is the Rouge Information Manager, also a user-friendly, readily transferable tool (an "electronic file cabinet") for accessing multi-media information about the Rouge River restoration effort.

Effective, readily transferable tools have been developed, employed by the Project, and are being shared with other cities and state agencies. Additional information on the Rouge Project can be obtained from the web site at *h ttp:\www. rougeriver. corn.*

Evolution of the Watershed Approach

The Rouge River watershed has seven subwatersheds that range in size between 19 and 89 square miles (See Figure 1). Older communities served by combined sewers dominate downstream portions of the Rouge River Watershed, while the headwater areas are typically open space, agricultural land, or low density residential developments that are undergoing rapid change due to growth pressures. Fully developed areas, typical of the middle portions of the Rouge Watershed, have separated storm sewers and limited opportunities to address stormwater problems with structural solutions.

Data gathered by the Rouge Project have shown numerous water quality and designated use problems, including high bacteria levels and low dissolved oxygen levels during wet weather events in all areas of the watershed. Fish consumption is prohibited in much of the watershed due to the threat to human health. Six of the seven subwatersheds have moderate to severe degradation of wildlife habitats, with fish populations suffering severe impairment in three of the subwatersheds. Aesthetic enjoyment is moderately to severely impaired throughout the watershed. Restrictions to small boat navigation resulting from logjams, garbage and sedimentation are a moderate to severe impairment in virtually all seven subwatersheds.

Based upon what was learned, the focus of the Rouge Project became more holistic to consider impacts from all sources of pollution and use impairments in receiving waters. The historic implementation of water quality management programs in the United States at the federal and state levels has been to focus on point sources, which are the most obvious sources of pollution to water bodies. This approach has worked well to control pollution from most point sources but has also left a patchwork of regulated and unregulated discharges of stormwater and nonpoint source pollution to surface waters. This patchwork is especially evident in most urbanized areas where multiple local jurisdictions are located in the same watershed. More subtle sources of pollution, such as stormwater, have emerged as the next priority for attention. The challenge for the Rouge Project became to develop innovative, coordinated solutions to achieve water quality objectives that may be: (1) be more cost-effective, (2) implemented in a more timely fashion, and (3) better able meet local needs.

It has become clear that water resources management must have the support of the general public in order to be effective and to become self-sustaining. A locally driven watershed approach to pollution management as a means to achieve management goals is an exciting concept discussed by many, but for which there is limited practical experience. This is particularly true in urban situations where there are multiple sources of impairment to a water body and stiff competition for limited local resources to address the pollution sources. The Rouge Project has provided a unique opportunity for a watershed-wide approach to restoring and protecting an urban river system by using a cooperative, locally based approach to pollution control.

The Michigan NPDES General Permit for Municipal Stormwater Discharges

As concern expanded to sources of pollution in the upper portion of the watershed above the CSO discharges, and water quality improvement focused more on watershed-wide approaches, the lack of a defined regulatory framework to address stormwater pollution and diffuse nonpoint source pollution became a major obstacle to further progress in improving water quality and restoring beneficial uses to the Rouge River. Beginning in 1995, the Michigan Department of Environmental Quality (MDEQ), the Rouge Project, and the communities in the Rouge Watershed jointly developed an innovative, watershed-based NPDES general permit ("General Permit") for municipal stormwater discharges. The permit was issued on July 31, 1997 (MDEQ, 1997). This collaborative process was outlined in a report entitiled "Adapting Regulatory Frameworks to Accommodating Watershed Approaches to Storm Water Management" (Fredericks, et al., 1997).

The MDEQ General Permit and USEPA's draft Phase II stormwater regulations (U.S. Environmental Protection Agency, 1998) due to be promulgated in September 1999, were developed during the same time frame. Wayne County, on behalf of the Rouge Project communities, was selected to serve on USEPA's Urban Wet Weather Flows Federal Advisory Committee, which (among other activities) assisted USEPA with the development of the Draft Phase II Stormwater Regulations. Participation on the federal advisory group on watershed approaches to stormwater management was invaluable to the development of the Michigan General Permit, and provides a high likelihood that the General Permit will be acceptable for implementing the forthcoming federal Phase II Stormwater Regulations in Michigan.

The General Permit incorporates the following elements:

General:

- Permit coverage is voluntary until the final EPA Phase II Stormwater Regulations are promulgated

- Public agencies who own, operate, or control stormwater systems are provided the opportunity for coverage

- Watershed size is established by the potential permitees during the application process

- Application and permit process have limited required actions; the focus is to establish desired outcomes.

Requires permittee to develop the following:

- *Illicit* Discharge *Elimination Plan* (IDEP) that has the goal of eliminating raw sewage discharges and includes addressing failing septic systems and improper connections of sanitary sewers to storm drains and open waterways.

- *Public Education P/an* (PEP) designed to inform residents and businesses about what actions they should take to protect the river.

- In cooperation with others, a *Watershed Management P/an* to resolve water quality concerns which includes: short and long-term goals for the watershed, delineation of actions needed to achieve the goals, estimated benefits and costs of management options, an opportunity for all stakeholders to participate in the process.

- *Storm Water Pollution Prevention Initiative,* which includes evaluation and implementation of pollution prevention and good housekeeping practices and the evaluation and implementation of BMPs to minimize impacts of new development and redevelopment.

- *Monitoring and Reporting P/an,* which includes a schedule for revisions to the Watershed Management Plan.

The IDEP and PEP are submitted to MDEQ at the time of application and the implementation of these plans begins when the MDEQ issues a certificate of coverage to a community/agency. Within six months after the issuance of a certificate of coverage to a community/agency, the General Permit requires the submission of a public involvement plan for approval by the state. This plan identifies the approaches that will be used within the hydrologic area to involve stakeholders in the development of a watershed plan that must be completed within 18 months after the certificate of coverage is issued. Once a consensus, long-term management plan has been completed, each agency and community within the watershed must prepare and submit for state approval its own pollution prevention initiative that identifies actions and schedules to address the pollution concerns identified in the consensus watershed plan. The watershed stormwater management plans developed by the communities and other public agencies do not require state approval; however, the individual pollution prevention initiatives emanating from the watershed planning process do require state approval, as the activities specified in the initiatives become permit requirements upon approval.

Rouge Community/Agencies Approach to Application and Permit Requirements

A total of 43 communities and agencies who own, operate, or control stormwater systems in the Rouge River Watershed have obtained coverage under Michigan's new watershed-based General Permit for municipal stormwater discharges. The result is that over 95% of the watershed is covered under this new program. The communities and agencies requested that, for purposes of the General Permit, the large Rouge watershed be subdivided into the seven subwatersheds shown in Figure 1. Long-term management plans will, therefore, be developed for each of these subwatersheds, with coordination of the plans provided by the MDEQ and the Rouge Project staff. The document "Implementing a Model Watershed Approach Through a State General Storm Water NPDES Permit" (Cave, et al., 1998) outlines key issues discussed and decisions reached by the communities as they developed their General Permit applications during 1998. The following section presents additional information regarding the application and permit requirements recently approved for the communities and agencies in the Rouge Watershed under the Michigan General Permit.

The Michigan General Permit for municipal stormwater discharges is quite flexible and allows those seeking coverage under the permit to use a wide variety of approaches to meet the public education, illicit connection/illegal discharge, and public involvement requirements. This flexible framework has allowed communities to experiment with various approaches that recognize local constraints and seize upon unique opportunities to meet the desired outcomes. While the basic requirements for what must be in the watershed plan are more detailed, the permitees within a watershed are allowed considerable freedom in deciding upon their own priorities, remedial actions, and schedules. Pollution prevention initiatives that are expected to be proposed by the communities will likely involve commitments to continue or expand current activities, like soil erosion and sedimentation control; implementation of new activities to address priority issues such as failing septic systems; and implementation of regional projects to reduce the frequency and velocity of storm flows in the river.

Table 1 and Table 2 outline the variety of public education and illicit discharge detection and elimination approaches identified by the communities and public agencies in the Rouge Lower 1 Subwatershed (Figure 1).

Across the watershed, communities actively sought ways to cooperatively address illicit connection/illegal discharge investigations and public education projects. In one subwatershed group, a community with experience in the production of videos agreed to make a river stewardship video that all other communities within the subwatershed could use on cable television, or through the distribution of cassette copies to local libraries and/or schools. In the same watershed, another community offered the use of a consultant to solicit bids for freestanding public information display boards and to develop stormwater information materials for the boards that could be used by all communities at public gatherings and inside public facilities. One community obtained the support of the local college to house and provide administrative support for a well-established non-profit organization, the Friends of the Rouge organization, whose public information activities were subsequently funded by several subwatershed groups to implement portions of their public education plans.

Advantages of Watershed Approach

The following section presents some of the lessons learned as the communities and agencies in the Rouge Watershed are beginning to implement the watershed-based, Michigan General Permit for municipal stormwater discharges.

Holistic Solutions/Local Ownership. There are distinct advantages in managing stormwater on a watershed basis. From the work already completed on the Rouge Project, it is clear that an integrated approach is needed to address all sources of water pollution and excessive flows in this urbanized watershed. By requiring those agencies and communities with responsibility for stormwater to work together at the subwatershed level to establish goals and objectives, local agencies and the state regulatory agency are forced to view solutions holistically. To achieve the desired level of river restoration, there must be integrated action plans that address not only stormwater but failing on-site sewage disposal systems (OSDS), CSOs, sanitary sewer overflows (SSOs), and significant nonpoint sources of pollution.

Ideally, a watershed-based regulatory framework should encompass all dischargers so that pollution sources can be addressed holistically. Practically, it must be recognized that prior NPDES permit programs at the state and federal level are already in place for municipal and industrial point source waste treatment discharges, and for many industrial and commercial stormwater discharges. While the Michigan watershed-based stormwater General Permit covers only public agencies that own, operate, or control stormwater conveyance systems not currently under a Phase I Stormwater Permit, the required watershed management plan does provide aframeworkfor integrating activities under other permit programs. In addition, the General Permit gives communities and agencies the flexibility and encouragement to incorporate nonpoint source controls and pollution prevention activities as part of the required watershed management plan. For example, many

Table 1. Illicit Discharge Elimination Activities to be Implemented under Michigan Stormwater General Permit in Communities in Lower 1 Subwatershed, Rouge River Watershed

	Activity	Canton Township	Plymouth Township	Van Buren Township	Wayne County	Salem Township	Superior Township	Ypsilanti Township
Legal Basis	Existing ordinances for control of illicit connections and/or OSS have been determined sufficient or community/agency will evaluate existing ordinances	x	x	x		x	x	x
	Will adopt additional ordinances for control of illicit connections and/or OSDS if determined necessary	x	x	x		x		x
Locating Problem Areas	Review existing monitoring data to prioritize investigation areas	x	x	x		x		x
	Plan developed w/County to locate sources of suspicious discharges previously identified	x	x	x				x
	Develop, modify, implement and/or continue to use complaint system	x	x	x		x	x	x
	Procedure to coordinate complaint response/follow up	x		x		x	x	x
	Develop and/or use GIS for tracking complaints and/or activities	x				x		x
	Train field employees for identification & reporting of illicit discharges	x	x	x		x	x	x
	Mapping of storm system, jurisdictions and/or locations of outfalls	x	x	x				x
	Systematic dry weather screening of outfalls or manholes	x	x	x				
	Investigate possibility of systematic screening program					x		
	Screen drainage from facilities under jurisdiction						x	
Finding the Source	Dye testing when additions made to existing facilities	x						
	Establish priority of suspicious outfalls and/or initiate follow up visits for further analysis of flow	x	x	x				x
	Investigate to find sources of suspicious discharges using upstream manholes or dye testing or televising	x	x	x		x		x
Minimizing Seepage from Septic Fields and Sanitary Sewers	Identify and/or map areas served by OSDS			x				
	Determine feasibility of sewer extension/mitigation						x	
	Proposals for future sanitary sewer construction will consider existing OSDS			x				
	Develop agreement/cooperate with county for implementing an OSDS evaluation program	x	x	x				x
	OSDS evaluation prior to sale of property	x				x		x
	Continue sanitary sewer maintenance program	x	x	x			x	x
Reporting	Reporting to MDEQ on investigations, violations found & corrective actions taken	x	x	x		x	x	x
Other	Investigate Funding Mechanism for Stormwater Related Tasks			x				

Table 2. Public Education Activities to be Implemented Under Michigan Stormwater General Permit by Communities in Lower 1 Subwatershed, Rouge River Watershed

Activity	Canton Township	Plymouth Township	Van Buren Township	Salem Township	Superior Township	Ypsilanti Township
Cable TV ads	x		x		x	x
Clean Sweep program		x				
Coordinate with Master Composters Program						x
Co-sponsor annual River Day	x				x	
Co-sponsor educational workshops			x	x		
Co-Sponsor Healthy Lawn & Garden Workshop		x				x
Cosponsor informational outreach workshops						
Co-sponsor River Stewards program					x	
Co-sponsor River Watch program				x	x	
Co-sponsor Rouge River Day		x				
Co-sponsor Rouge Education Project	x	x		x	x	
Co-sponsor Rouge Friendly Neighborhood Program		x			x	
Co-sponsor Rouge Friendly Business Program		x				
Display maps of community, watersheds & boundaries				x		
Distribute miscellaneous brochures and/or fact sheets	x		x	x	x	x
Distribute Rouge Recreational Guide	x		x			
Distribute Rouge Repair Kit to homeowners				x		
Distribute septic system maintenance packet to homes with OSDS				x		
Distribute storm water general information package to new residents				x		
Heighten visibility & promote school water/resource monitoring				x		x
Periodically provide Rouge Information Kiosk system in public buildings					x	
Presentations	x		x		x	x
Provide articles, Information in community newsletter	x		x	x	x	x
Provide fliers/messages in water bills or tax notices					x	
Provide water quality educational information on Website					x	
Public service announcements					x	
Publicize garden hotline				x	x	x
Publicize illicit discharge hotline				x	x	x
Storm drain marking	x		x		x	x
Tributary signage					x	
Utilize "Our Actions" display at various community events	x		x		x	x

communities have initiated pilot projects to evaluate how stormwater best management practices (BMPs) will control stormwaterflow and prevent pollution. In some cases, these pilot projects have permanently changed the way communities and/or government agencies manage stormwater. These management practices will be included, as part of a watershed management plan, and credit will be given to the entities that are performing those functions.

Many of the subwatershed units selected in the Rouge River Watershed involve communities that have combined sewers, separated sewers, and OSDS. Some individual communities have all three within their corporate limits. Once the communities began to work together at the subwatershed level to establish goals to achieve water quality standards necessary to restore the river, each found that they had a significant role in the process and that the control of flow in the rapidly developing headwater areas was as significant as CSO problems in the lower portion of the watershed. Evaluating the sources of water quality problems and/or the threats to existing uses of the river at the subwatershed level by local agencies is leading to a better understanding of local constraints, opportunities for innovative solutions, ownership of the long-term river restoration effort, and interagency cooperation.

Overcoming Institutional/Regulatory Barriers. Local agencies and communities in urbanized areas have a long history of cooperative efforts to address the delivery of common public services. Recent trends in Michigan, and elsewhere in the country, to reduce the size and cost of government and limit local taxing power have accelerated efforts at the local level to integrate or share the cost of a broad range of government services. Local agencies are increasingly seeking ways with their neighboring jurisdictions to reduce the cost of police and fire protection, solid waste disposal, libraries, recreational facilities, infrastructure maintenance and repairs, public transit, water supplies, and sewage disposal. Unfortunately, except in a few isolated instances where a single authority has been created to oversee all aspects of water management, the legal responsibility for stormwater is widely dispersed among local communities, county health and drain agencies, road agencies, private developers, and autonomous school districts and public colleges. The creation of a new level of government in the form of a water management authority with broad powers has been resoundingly rejected in the Rouge River watershed by local agencies and is likely to receive the same reception in many other urban areas of the country.

State and federal water quality regulatory programs have traditionally focused on large point sources where responsibility for obtaining and complying with specific permit limits is easy to establish. The regulatory framework to control water pollution has generally discouraged rather than encouraged cooperative solutions among communities and has relied upon command and control to achieve results. The complexities involved in addressing wet weather pollution problems in urban areas, and the widely dispersed accountability for managing stormwater, demands a new regulatory framework that will encourage cooperation among the locally responsible public agencies to design integrated, holistic solutions. The watershed approach to stormwater regulation developed in Michigan offers an opportunity to overcome the institutional and regulatory impediments that have discouraged cooperative local approaches to restoring urban watersheds.

Institutional arrangements and financing options necessary to implement the General Permit and subwatershed management plans are among the many elements the local communities in the Rouge Watershed are addressing in their working groups. As part of the subwatershed planning process, communities and agencies are also identifying issues which cross subwatershed boundaries. Rouge Project staff and the MDEQ currently provide coordination of individual subwatershed efforts and assist subwatersheds in developing a comprehensive strategy for addressing watershed-wide issues. The subwatershed communities are also identifying those activities, such as public education and water quality monitoring, that may be most cost-effectively performed throughout the entire watershed by a single entity.

Increased Local Accountability and Political Support. Building a watershed restoration project from the bottom-up by helping local communities and agencies identify problems, set their own priorities for restoration, select their own remedial measures and propose their own schedules requires a sharing of power among federal, state, and local agencies not usually found in water pollution control programs. The General Storm Water Permit program in Michigan is voluntary at this time and it has allowed state regulators the ability to provide flexibility that might not otherwise be available. It has also increased the accountability of local agencies who no longer have the freedom to blame federal and state officials for the impositions of requirements, but now are responsible for convincing local elected officials that the programs proposed are in the best long-term interest of the local residents.

Opportunities for Cost Eff iciencies/lnnovation. As discussed earlier, the Rouge River communities that have obtained coverage under Michigan's General Storm Water Permit and are working in subwatershed groups have already developed more cost effective and efficient methods to meet public education requirements through cooperatively developed projects. Similar joint programs are underway to train local community and agency staff in illicit discharge elimination activities and in sharing staff and equipment to conduct river and enclosed storm drain surveys. The three county health agencies are developing common approaches to permitting and inspecting OSDS. The county road agencies are working with the state highway agency to address the design, construction, and maintenance of transportation drainage systems.

The county agencies in the three counties responsible for designated storm drains are working together and with local communities toward implementing common standards for stormwater management at new developments. County and local officials have worked together to establish protocols for rapidly developing independent GIS to assure that databases can be integrated to assist in watershed-wide water quality/quantity management. The economic and political cost for each community or county agency to develop these approaches has been an impediment in the past. The watershed approach has enabled these cooperative programs to be established. It is anticipated that the pollution prevention initiatives required following completion of the watershed management plans would also involve joint projects.

Establishing a broad range of cooperative programs to address stormwater problems across jurisdictional boundaries is, in of itself, innovative. However, with the development of comprehensive watershed plans, new practical approaches to implementing total maximum daily load (TMDL) requirements of the Clean Water Act and effectively using water pollution trading options created at the state level become possible. The Rouge River National Wet Weather Demonstration Project is funding a pilot program to verify that the watershed management framework under the Michigan Stormwater General Permit can be used to meet the TMDL requirements, ahead of state schedules (and at potentially lower cost), and the objectives of the Clean Water Action Plan program. In addition, the pilot program will demonstrate how the General Permit watershed framework can be used as a basis for the proposed statewide water quality trading program currently under development.

The top-down, command-and-control approach often requires repeated threats or legal action by state and federal regulators to ensure compliance with requirements due to lack of political will at the local level. Locally generated watershed plans containing specific action schedules that have been adopted by elected boards, commissions, and councils are less likely to be abandoned or require enforcement actions to assure compliance. Peer pressure and citizen support at the local level should be sufficient incentive in most instances for each local agency to complete their responsibilities on schedule. Where legal enforcement action is required, the state and federal agencies are more likely to find support among other local agencies who have met their obligations as outlined in the joint subwatershed plan.

Conclusions and Recommendations from a Community Perspective

Local communities in southeast Michigan and the state regulatory agency are attempting, for the first time, a consensus, cooperative approach to stormwater management and regulation under the NPDES program. The Michigan General Permit is a watershed-based, general stormwater permit issued under the National Pollutant Discharge Elimination System. The permit requires permitees to immediately initiate activities, such as illicit discharge elimination, and to participate in watershed management planning for a self-determined hydrologic unit. The watershed management plan forms the basis for implementing watershed goals and objectives, including improved water quality and pollution control. This new regulatory program implements the watershed approach endorsed by USEPA and others and should facilitate watershed-based integration of control programs for different pollution sources, such as stormwater CSOs which may be present within a large, urban watershed. In addition, it is believed that the new watershed-based stormwater program in Michigan will achieve the objectives of the TMDL program, the Clean Water Action Plan Program, and water quality trading programs under development across the country. From the perspective of local communities and agencies, this approach provides optimum flexibility to solve the most pressing problems in their subwatersheds by empowering them to identify problems, choose from alternative solutions, establish priorities and schedules, and develop common strategies with neighbors. Communities and others involved in this new program are also addressing issues such as coordination of subwatershed efforts within larger watersheds.

The Rouge Project (and others) have shown that by holistically addressing all sources of pollution, a cost-effective action plan can be implemented to address impairments and restore river uses. Storm water issues cannot be corrected in a vacuum, but must be integrated into an overall solution that addresses the physical, chemical, and biological stressors in a waterway. Stormwater adversely affects all three and, therefore, must be woven into the fabric of the overall watershed management plan and watershed control program. Without this integration, stormwater control will become another “add on” program that misses an opportunity to encourage an integrated program that addresses all sources of ecosystem stress in a cost-effective, prioritized manner. The approach being followed in the Rouge River Watershed should prevent misplaced efforts and, most importantly, result in a restored Rouge River on a much faster timetable.

A key objective of the Rouge River National Wet Weather Demonstration Project has been to demonstrate alternative methods to a “command and control,” top down regulatory approach for water quality protection and improvement. The alternative methods sought by the Rouge Project leverage “bottom-up” approaches that put place-based needs in the forefront and use local initiatives to make progress on water quality restoration. This approach has led to a number of institutional changes in the watershed that will help sustain the watershed management efforts into the future. From the perspective of the communities involved, the cooperative, iterative approach being followed appears to be working and is a welcome change from traditional “command and control” relationships with regulatory agencies.

The Rouge Project approach demonstrates that watersheds can be “managed.” When water quality objectives can only be reached through control of CSO, stormwater, and nonpoint sources, watershed management must involve the active participation of local units of government. From a community perspective, this local involvement is critical to the overall success of the Project and to stream restoration. Also, from a community perspective, undertaking a watershed effort is not a simple matter. Watershed planning and implementation takes a large commitment of time and effort.

The communities involved in the Rouge Project have a sense of overwhelming success with the watershed restoration efforts to date. Water quality and ecosystem health are improving, and the demonstration techniques have resulted not only in concrete and steel structures, but in real institutional changes that integrate the work of stormwater and watershed improvement into the basic institutions of government. Most importantly, the public is able to utilize new canoeing areas and other river-based amenities, which are now possible due the noticeable improvement in water quality, aesthetics, and other attributes of the river. It is hoped that this effort, and the work of the Rouge River National Wet Weather Demonstration Project, will continue to identify and quantify the benefits of cooperative, watershed-based efforts to protect and restore our nations water resources.

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California's Model Urban Runoff Program (MURP): Urban Runoff Programs for Small Municipalities

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Background

Monterey Bay is a crown jewel of the California Coastline and has received special protection under the National Marine Sanctuaries Act since September 1992, and the California Coastal Act since 1976. The 5,300 square mile Monterey Bay National Marine Sanctuary includes a number of small coastal communities, and ranges from the City and County of San Francisco on the north to Cambria on the south. The cities of Monterey and Santa Cruz have long recognized that protection of the unique marine resources within the Sanctuary is critical to the economic vitality and quality of life of their communities. Monterey Bay, with its world renowned Monterey Bay Aquarium, rich bird and marine resources, recreational opportunities that include the Santa Cruz Boardwalk, and commanding vistas has become a major tourist attraction.

The Cities of Monterey and Santa Cruz developed and implemented a Model Urban Runoff Program (MURP) in a cooperative team effort with the Monterey Bay National Marine Sanctuary, the California Coastal Commission, California Regional Water Quality Control Board-Central Coast Region, and the Association of Monterey Bay Area Governments (AMBAG) funded by an EPA 319(h) grant. The MURP was developed to address and support a number of environmental regulations and initiatives that applied to the Sanctuary and adjacent coastal areas including: the Sanctuary's Water Quality Protection Program, requirements of the Coastal Zone Act Reauthorization Amendment (CZARA), Coastal Commission plans and policies, the Regional Board's watershed management initiative and basin plans, the State Water Resources Control Board's Ocean Plan and Nonpoint Source Pollution Control Program, and EPA's proposed draft Storm Water Phase II Rule (Storm Water Phase II).

The concept of the MURP originated in the Sanctuary's Water Quality Protection Program for Monterey Bay National Marine Sanctuary-Action Plan Implementing Solutions to Urban Runoff and a State's Urban Runoff Technical Advisory Committee Report, developed to address Section 6217 of CZARA.

One of the most important drivers in the development and implementation of the MURP was an initiative of municipal leaders to address the value that the community places on protecting the local creeks, streams, and wetlands and the Sanctuary's marine biological resources.

Development of Model Urban Runoff Program

A key objective of the MURP was to produce a document that would assist other communities in the development of their own urban runoff programs by providing an off-the-shelf "how-to" guidebook building on the experience gained through the development and implementation of Phase I Storm Water Management Programs. A second objective of the project was the development of Urban Runoff Management Programs for the cities of Monterey and Santa Cruz that would address the community's values and achieve early implementation of and compliance with the various regulatory programs and initiatives.

Representatives from Phase I municipalities who were responsible for the development of their programs and had gained experience in implementation were consulted throughout the project. They participated in workshops when the MURP was presented to Monterey Bay municipalities and provided extensive information and examples of material used in their communities, including what worked and what didn't. Woodward-Clyde Consultants, with its extensive experience in working with Phase I municipalities, was selected to assist the project team in developing and producing the MURP.

The cities used a conceptual framework for developing urban runoff programs appropriate for their individual needs following the guidance recommended by the MURP. It included four major steps:

- Assessment – Institutional assessment and assessment of environmental resources and sources of pollutants of concern
- Development – Program management, institutional arrangements and coordination, legal authority, and fiscal resources
- Implementation – BMPs and model programs for each of the six control measures proposed in Storm Water Phase II and for control of commercial and industrial activities
- Evaluation – Progress reporting and evaluation, water quality monitoring, and program update.

Periodic meetings were held during the two-year grant period to share, review, and comment on individual city work products, review progress, prepare and validate the MURP, and discuss early implementation actions. The Sanctuary was instrumental in the early implementation effort by providing public information and outreach support and developing public education materials. The Coastal Commission played an active role in formulating strategies for addressing Sanctuary-wide water quality and land use concerns and providing support in the development of GIS-based land use maps. Project status reports were presented to the Monterey Bay Regional Stormwater Management Task Force, AMBAG, city councils, and Monterey Bay area public works officers.

The Model Urban Runoff Program

The MURP contains these four major steps for the development and implementation of an urban runoff program, and a corresponding appendix containing additional information, examples, models, references, and contacts for further information.

The Assessment Phase of the MURP describes the importance of information gathering and research to provide an early survey of the municipalities, current policies, programs, legal authorities, and fiscal resources applied to control urban runoff. A similar institutional assessment of existing regional storm water, watershed, and other water quality control programs is recommended to avoid duplication and to identify potential conflicts, opportunities for coordination, and areas not previously addressed. This phase also provides guidance and methods for (1) describing a community's water resources and activities that can be impacted by polluted runoff, (2) mapping the storm drainage system, (3) developing a relationship of pollutant sources/activities to pollutants of concern, and (4) developing a working map to assist in targeting problem areas or pollutant sources. Coordination with and building upon existing efforts, including joining Phase I programs, is encouraged.

The Development Phase of the MURP describes the (1) selection of the program management structure, (2) identifies individual and departmental responsibilities for management of individual program elements (public education, control measures, or BMPs) and (3) coordination with other internal and external programs and agencies. The legal authority to ensure implementation of BMPs and achieve compliance with the MEP standard of the Clean Water Act was developed through use of a model ordinance. The appendices include examples of language for the amendment of Local Coastal and General Plans as required by the State of California. Revisions to the California Environmental Quality Act checklist were recommended to provide planners an additional tool to evaluate impacts of runoff from both new development and re-development. This Phase includes an estimate of staffing resources to implement each element of an urban runoff program. It also describes the use of assessment districts, storm water utility fees, and other sources of funding program implementation.

The Implementation Phase of the MURP describes eight program elements including six required by EPA's Phase II draft regulations as minimum requirements MURP program elements include (1) public involvement/participation, (2) a public education and outreach program, (3) an illicit connection and discharge detection and elimination program, (4) a municipal operations control program, (5) a construction site discharge control program, (6) a new development/redevelopment control program, (7) an optional control program for commercial facilities, and (8) an optional control program for industrial facilities. The MURP recommends objectives, BMPs, implementation activities, and methods for program evaluation and documentation. This includes measurable goals for each of the eight program elements. The appendices contain numerous examples of public participation and education; BMPs for residential areas, food service operations, municipal operations, construction sites, vehicle service facilities, and shopping centers; sample SWPPPs for corporation yards and construction sites; and reporting forms.

The Evaluation Phase describes methods for (1) determining whether water quality is improving and whether the efforts and resources are directed at the right source and pollutants of concern; (2) reporting progress using the BMP measurable goals, and (3) the developing and implementing of water quality monitoring programs and volunteer monitoring programs. This phase provides and stresses the need for procedures for modifying and updating the urban runoff program using the evaluation tools.

Each section of the MURP contains an extensive list of references to assist municipalities in obtaining additional detailed supporting information on how these programs were developed.

Implementation of the Model Urban Runoff Program

Municipalities in California's major metropolitan areas were encouraged, and in some cases required, to file for NPDES' permit coverage on an area-wide basis. Numerous smaller municipalities are already regulated by Phase I requirements. There are now approximately 260 municipalities, with a combined population of 29 million, regulated by Phase I NPDES permits in California.

In California, 76 incorporated places and counties are proposed to be automatically designated and 38 areas outside urbanized areas that could be potentially designated under Storm Water Phase II. The Monterey Bay Area has 13 incorporated places and counties that would be automatically designated. The MURP will be of significant benefit to a number of smaller California municipalities, and particularly in the area covered by this project.

Undertaken as part of a 319(h) Grant, this project was required to conduct an outreach effort to ensure early implementation of urban runoff programs. Two workshops were held in April of 1998 for planning, public works, building, parks, public information/education, and general municipal operations staff in the Monterey Bay Area. These workshops, attended by approximately 120 individuals, covered an introduction to urban runoff pollution, and regulatory requirements. They featured presentations from individuals experienced in the development and implementation of Phase I storm water management programs and included four break-out workshops covering MURP development and implementation.

The agencies participating in the development of the MURP have undertaken a number of actions, described in the following paragraphs, to implement the project recommendations.

City of Monterey

During the development of the MURP, the City of Monterey mapped watersheds, major storm drains, key streams, creeks and channels. They also identified and mapped automotive servicing facilities, restaurants, several industrial sites, and pest and weed management activities as potential sources of runoff pollution. Fifteen potential sources or activities that could contribute primary pollutants of concern were identified. The City has adopted a water quality ordinance and established a monthly storm water utility fee, currently $3.43, to implement its urban runoff management plan.

In cooperation with the Sanctuary and Coastal Watershed Council, the City has also initiated a citizens participation program to label storm drain inlets and perform volunteer monitoring (Urban Watch Stormdrain Monitoring Program). This volunteer effort led to the development of a Restaurant Outreach program to educate employees and eliminate pollution. The City has commenced implementation of BMPs for new and existing sources, conducted water quality monitoring, distributed public education material, and is currently working to implement its construction site pollution prevention program.

In cooperation with the Sanctuary, the City has obtained a grant to install and test storm water treatment devices at the Monterey Harbor and Fisherman's Wharf parking lots to determine the effectiveness of removing oil, sediment, and trash.

City of Santa Cruz

The City of Santa Cruz developed a computer-generated map of watersheds and land uses to identify potential pollutant sources. The City adopted a storm water ordinance in April 1998, regulating all water entering the storm drain system, prohibiting illicit discharges and connections, and requiring implementation of BMPs published by the City. The City has drafted BMPs for vehicle service facilities, retail shopping areas, residential areas, and food service facilities. The City Industrial Waste Inspectors will conduct initial inspections of 100 vehicle service facilities in 1999 to determine any actions which must be taken to comply with the ordinance, with second inspections scheduled to formally determine compliance. The City hosted an outreach presentation of the program and the proposed BMPs for the business community during its Pollution Prevention Week.

City of Watsonville

The City of Watsonville began implementing a storm water program in 1991, through its industrial facilities Source Control Program, and completed a bilingual storm drain stenciling program in 1992. Subsequent to the development of the MURP, the City has completed a review of existing programs and policies, developed a new storm water ordinance, started an illicit connection program that has sampled 50% of the City's storm drain outfalls, and established a public education program in cooperation with the Sanctuary. The City plans to implement a municipal, industrial, and commercial source control program, a targeted educational outreach program, and a construction and new development program.

Monterey Bay National Marine Sanctuary

The Sanctuary's Water Quality Protection Program addresses a number of water quality issues in addition to urban runoff and targets nonpoint sources of pollution. The Sanctuary's program supports the cities' urban runoff programs by developing and distributing educational materials on urban pollution and co-sponsoring teacher training workshops with the Monterey Bay Aquarium. It also collaborates with the City of Monterey on volunteer monitoring programs and public education. The Sanctuary has prepared a plan for addressing polluted runoff from agricultural lands and has received commitments from the California Farm Bureau and six regional Farm Bureaus to form a coalition to address this issue. The Coalition will focus on educating its members on polluted runoff, establishing landowner committees and pilot projects in several watersheds, and strengthening farm management practices by developing grower self monitoring and serving as a liaison with the Sanctuary and the Regional Board.

The Sanctuary and the City of Monterey have a cost-sharing agreement, which funds a Sanctuary employee at half time in return for the development of a City public education program. This agreement is going into its third year, and has resulted in the development of public education brochures, posters, exhibits, BMP pamphlets, and the Restaurant Outreach Program. Current work is focused on the development of a Public Service Announcement, a construction site education program for developers and inspectors, and signage for Monterey's Harbor.

State of California - Coastal Commission and Regional Water Quality Control Board

Implementation of the MURP has been identified as a priority in the California Nonpoint Source Pollution Control Program's first 5-Year Implementation Plan, which the State Water Resources Control Board and California Coastal Commission developed pursuant to the Clean Water Act and Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Key actions that the State will undertake include the distribution of copies of the MURP Guidebook to California cities and the providing of technical support and training to cities developing Urban Runoff Management Plans using the MURP.

The Coastal Commission intends to review the experiences of Monterey Bay Area cities in implementing the MURP and coordinating with the Central Coast Regional Water Quality Control Board to revise the MURP Guidebook as needed. The document will be made available to other small coastal cities by printed copies, CD-ROM, or Internet web site.

Summary and Conclusions

The Model Urban Runoff Program project, which is funded through a 319(h) Grant has provided small communities in the Monterey Bay Area an excellent opportunity to develop their own urban runoff programs and to develop and validate an off-the-shelf " how-to" guidebook on development of urban runoff programs. The MURP will potentially benefit over 100 communities in California that will be required to develop urban runoff programs implementing the six minimum control measures contained in EPA's draft Storm Water Phase II Rule and the requirements of Section 6217 of the Coastal Zone Act Reauthorization Act.

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New Stormwater Treatment BMPs: Determining Acceptability to Local Implementing Agencies

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Over 200 local governments in the Puget Sound watershed of western Washington require new developments to install stormwater treatment systems. The retrofitting of existing developments is also often required. With the guidance of the State of Washington', each local jurisdiction developed a list of approved treatment technologies, mostly public domain technologies such as wet ponds and swales, in the mid-l 990's. Having an approved list raises the issue of how to add new unapproved technologies, in particular the manufactured technologies such as swirl concentrators and drain inlet inserts. A protocol is needed by which local jurisdictions can determine acceptability of "unapproved" treatment technologies. This paper presents a protocol* recently developed to assist local jurisdictions in the Puget Sound watershed.

Protocol Structure

The protocol has four parts:

1. Performance criteria to compare currently unapproved treatment technologies with currently approved treatment technologies.

2. Types of data to be used in the evaluation and methods of sample collection.

3. Factors that are to be considered in the evaluation other than performance.

4. Content of the report provided to the local jurisdiction by the proponent.

Method to Compare Performance

There are many problems inherent in the development of a protocol, not the least of which is that there is no agreed-upon definition as to what constitutes acceptable performance against which to judge equivalency. An informal "standard" that is much discussed and that has been adopted by some jurisdictions outside the Puget Sound region is 80% Total Suspended Solids (TSS) removal over all storms less than a specified event.

A one-number standard of 80% may be inconsistent with two complementary observations about the performance of stormwater treatment systems. The first observation[3] is that removal efficiency of sand filters is directly related to influent concentration: the higher the influent concentration the greater the efficiency. This relationship may hold for other treatment technologies. The second observation' in Schueler (1996) proposes that there is a lower limit to the effluent concentration.

Further, a reasonably strong and direct relationship exists between runoff rate and TSS concentration[5]. This is particularly germane to our region with its mild storm intensities. A comparison of data from our region to areas with higher average rainfall intensities indicates that we tend to have lower TSS concentrations in untreated stormwater. It is therefore possible that over an aggregate of storms, we cannot achieve 80% TSS removal in the Puget Sound region.

A more appropriate method to compare approved and unapproved technologies may be to relate efficiency to the influent concentration. This approach allows the pooling of data from sites with different pollutant concentrations.

The protocol presumes that if we are satisfied with the technologies that are currently approved, we should approve an unapproved technology with similar performance. Therefore, the starting point is to identify the performance of currently approved technologies: swales, wet vaults, wet ponds, constructed wetlands, and sand filters. The results are presented in Figures 1 through 3. The data points in the figures are of flow-weighted composite samples from individual storms. Only data from studies conducted in the maritime climate of the Pacific Northwest are used.

Although this is a large region, from northern California to southwest British Columbia, comprehensive studies have been conducted only in western Washington. Data considered acceptable are from two wet ponds, three grass swales, and two sand filters. The protocol' provides detail on the studies that were reviewed. The reasons for using only Pacific Northwest data differ with the technology. With wet ponds there is concern about the possible effect of differences in regional climates on effluent quality. For sand filters, possibly because of differing sand chemistry, filters used elsewhere may be able to remove dissolved phosphorus[6] and zinc', a capability our sands do not have. Swales studies conducted elsewhere do not provide the information needed to judge whether they were sized to criteria similar to that used in our region.

Figure 1 for TSS is used in all comparisons, and is the first performance requirement that must be met. If the receiving water is nutrient sensitive, Figure 2 is also used. If the water body is of regional significance because it supports salmon, a central issue in our region, Figure 3 is also used. Zinc was selected to represent all toxics primarily because it is the only toxic with influent concentrations that are commonly high enough to allow for the evaluation of efficiency.

Each figure has a "Line of Comparative Performance," the origins of which are discussed later. Each line is drawn so that most of the data points fall above and to the left. This is called the region of acceptable performance. The data points of the unapproved technology under consideration would be plotted using the same format. If most of the data points fall above and to the left of the "Line", it can be concluded that the candidate technology is reasonably equivalent. What constitutes "most" is up to the local jurisdiction. The protocol does not specify a hard rule but offers these suggestions as to the percentage of data points falling above the "Lines": TSS, 90%; phosphorus, 80%; and zinc, 90%. Note that low efficiencies generally occur at low influent concentrations.

FIGURE 1 TSS Evaluation

PNW data - Individual storms

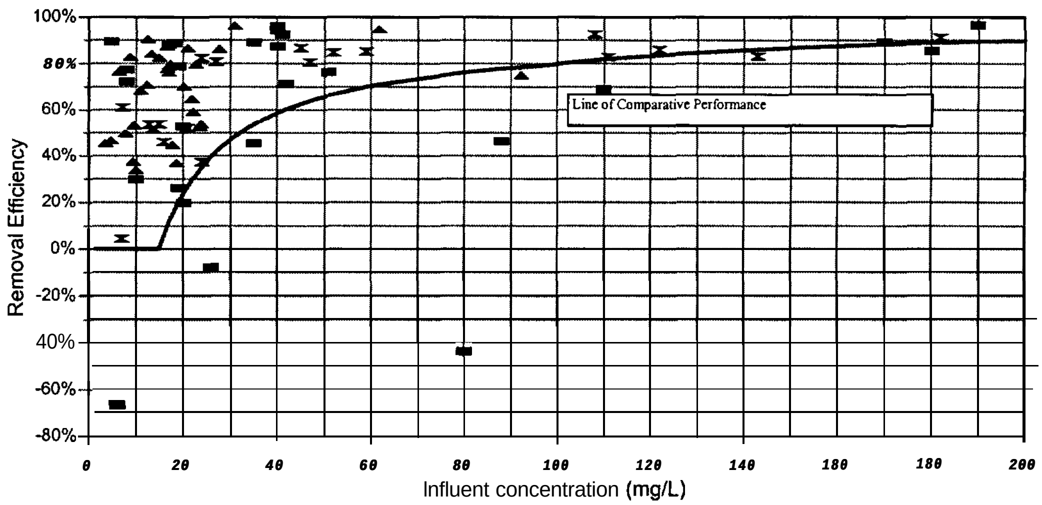
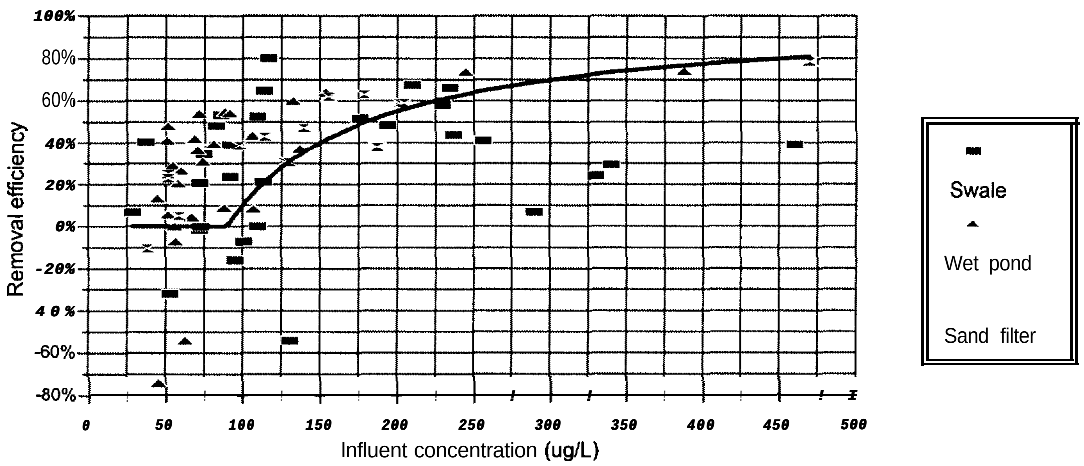


FIGURE 2 Phosphorus Evaluation

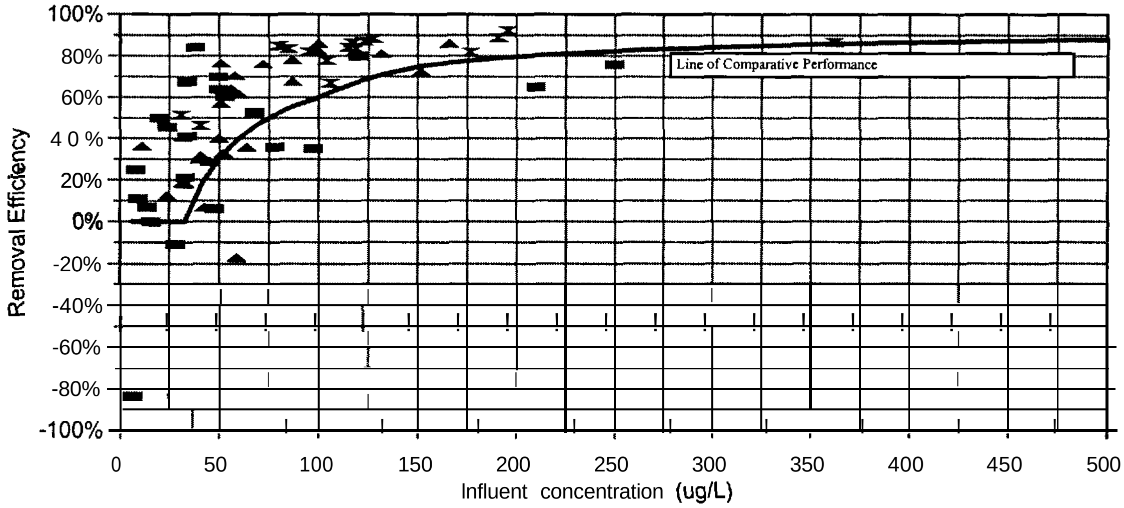
PNW data - Individual storms



How were the "lines" derived in Figures 1 through 3? Judgment was used to select a point of "irreducible" concentration, and to draw the line from this point to the upper right. Regarding "irreducible" concentrations: for TSS Tom Schueler has proposed[4] 20 to 40 mg/L, depending on the treatment BMP. A value of 15 mg/L was selected because the data in Figure 1 suggest that 15 mg/L is attainable. For TP (Figure 2), Schueler[4] proposed a concentration of 140 to 330 ug/L, depending on the treatment system. A lower value of 90 ug/L was selected for the same reasons as with TSS. Schueler[4] drew no conclusions with regard to zinc. However, his analysis[4] suggests "irreducible" concentrations of 36 ug/L for ponds and wetlands, so 35 ug/L was selected. It should be noted in Figures 1 through 3 that most of the incidents of low or negative efficiency occurred at low influent concentrations.

FIGURE 3 Zinc Evaluation

PNW data - Individual storms



Attempts were made to identify a line of best fit from which confidence limits could be derived under varying assumptions such as excluding all data below a particular influent concentration and/or removal efficiency. However, the relationships were so poor as to make confidence limits meaningless. It was concluded that basing the lines on some sort of statistical construct would give an air of rigor that is unwarranted at this time. Therefore, the lines were drawn using best professional judgment. It is expected that the Lines of Comparative Performance will change with time as additional data are collected.

Figures 1 through 3 can be used for inlet inserts if these pollutants are being considered. If, however, an insert is being considered for the removal of petroleum hydrocarbons, it must be compared to the effectiveness of oil/water separators. A graph comparable to Figures 1 through 3 is not provided for oil/water separators because of the lack of data. The criterion commonly used in the Pacific Northwest is that the concentration of individual samples shall not exceed 15 mg/L. This protocol could be used to generate data to compare to this criterion.

Data and Data Collection

It is the responsibility of the proponent of the unapproved technology, either the manufacturer or the development engineer, to obtain the required data. The protocol identifies the minimum requirements. Local jurisdictions are free to request more data. The protocol specifies the requirements for three sources of data: field studies with real storms, field studies with artificial storms, and laboratory tests. The protocol calls for discussion of advantages and disadvantages of each method. It is left to the local jurisdiction to decide the weight to place on each source of data. However, the protocol recommends that the local jurisdiction not rely solely on laboratory tests, particularly when considering the removal of dissolved pollutants or oil/grease and related products. It also recommends a size distribution of sediment for the laboratory tests.

The protocol is very specific with regard to the types and amounts of data that are to be collected. This aspect of the protocol is summarized in Table 1.

Table 1. Data Requirements

Item	Requirement
Number of test sites	One to three sites: medium density residential, retail commercial, and non-retail commercial.
Number of sampled storms	A minimum of 10 per site, total of 30 if one site
Storm depth	50% to the design storm depth (1.35' to 1.70")
Runoff duration	50% to 200% of the mean annual storm duration (7.5 to 30 hours)
Average rainfall intensity	50% to 200% of the mean annual intensity (0.02 to 0.08"/hour)
Type of samples	Flow-weight composite
Minimum aliquots per storm	10
Storm volume sampled	Samples are to be taken over not less than 75% of the total volume of each storm
Parameters	TSS, pH, total zinc, copper, and cadmium, TP, BAP, and TKN. include dissolved metals and phosphorus if it is claimed that the technology can remove dissolved constituents. With catch basin inserts where the sole objective is the removal of petroleum hydrocarbons, measure oil/grease, TPH, TSS, and pH.
Additional	At the end of the test period, the sediment accumulated in the treatment system shall be removed, quantified, and anlyzed. The sediment shall be evaluated for total dry weight, moisture content, particle size distribution, organic content, and zinc. Use ASTM wet and dry sieve test procedures to analyze the particle size distribution. Also determine the amount of floatables, i.e. litter, and petroleum products.

The protocol states that for a data point to be used in the analysis of efficiency, the influent concentration of the parameter shall either be at least ten times its detection limit, or be greater than the "irreducible" concentration, whichever is greater.

Efficiency is to be calculated three ways.

Method 1: Removal in each sampled storm calculated as:

100 (average influent - average effluent)/average influent

Method #1 is required because it provides the data points to plot figures like Figures 1 through 3.

Method 2: Aggregate removal of the sampled storms as:

100(A-B)/A

Where: A = (influent conc. Storm 1)(flow Storm l)+(influent conc. of Storm 2)(flow of Storm 2)

+ . . . (influent conc. of Storm N)(flow of Storm N)

B = (effluent conc. of Storm 1)(flow of Storm 1)+(effluent conc. of Storm 2)(flow of Storm 2)

+ . . . (effluent of Storm N)(flow of Storm N)

Method #2 is specified because it provides an overall efficiency of removal over the period of the research. If the amount of sediment that has accumulated in the bottom of the treatment facility has been determined from the separate lab test (See Section A.4), another calculation can be done to check the above estimate of efficiency. This second calculation is done as follows: subtract B from A, and then compare this difference to the amount of sediment determined from the separate laboratory test described in Section A.4. These calculations can also be done for zinc and phosphorus.

Method #3 Efficiency based on geometric mean:

100(A-B)/A

Where: A = geometric mean of all influent samples

B = geometric mean of all effluent samples

Method #3 is specified because it is the most correct method of calculating efficiency, although it has been used sparingly to-date. All influent and effluent data from multiple sites can be pooled.

Consideration of Factors Other than Performance

The protocol suggests that the local jurisdiction consider additional factors in making a decision should the technology pass the first requirement of acceptable performance. The protocol recommends the following factors, although the local jurisdiction is free to include other factors.

- Site characteristics
- Constructability
- Reliability
- Robustness
- Receiving water sensitivity
- Groundwater risk
- Operation and maintenance
- Habitat creation
- Thermal effect
- Aesthetics
- Recreational use
- Community acceptance

It is left to the reviewer to place a weight on the relative significance of each factor and to develop a scoring system. For example, the factors could be categorized and weighted as: "critical/necessary," "important," and "desirable." A relative score, say 1 to 10, could be identified for each factor, and multiplied by the corresponding weight of each of the categories.

Content of the Applicant's Report

The proponent of the technology is responsible for producing a report for the local government conducting the evaluation. The protocol provides a very detailed list of items that are to be included in the report.

Explanation of the technology, such as:

- How it works, how it removes pollutants
- Where it is currently being used
- Available models
- Treatment and hydraulic capacities of each model
- Documentation of the treatment and hydraulic capacities
- Sediment storage capacities of each model up to the point of recommended maintenance
- Floatables storage capacities up to the point of recommended maintenance
- Sizing methodology

- Materials used in the construction of the product
- Recommended maintenance procedures and frequencies

Documentation of the field studies:

- A description of the test site including: total acreage, total impervious acreage, a description of landscaping if relevant, the acreage draining to the device if it differs from total acreage. A description of the drainage system including the size of the sumps, and whether the sumps were cleaned prior to or during the test period
- A description of the model used
- Complete drainage calculations showing the calculations to size the treatment device
- All raw data including laboratory reports. All data are to be reported including rejected data with an explanation for the rejection
- Statement from the analytical laboratory certifying that the appropriate procedures were followed in the preservation and analysis of the samples
- Calculation of efficiency of each storm by comparing influent and effluent concentrations
- Calculation of the efficiency for all storms by comparing the total aggregate inflow loading of all storms to the total aggregate outflow loading for all storms
- A graphic of data points showing influent concentration versus efficiency for each storm sampled for TSS, zinc, and phosphorus. Plot all data, including rejected data, with an explanation for the rejection
- Start and end times of the precipitation and runoff periods of each sampled storm.
- Start and end times of the sampling period of each sampled storm
- Antecedent conditions during the 72 hours prior to each sampled storm
- Total rainfall depth of each sampled storm
- Total runoff volume of each sampled storm
- Runoff volume that occurred during the period of sampling of each sampled storm
- Total rainfall during the period of all of the sampling, i.e. from the first storm sampled through the last storm sampled
- Total runoff that occurred during the period of all of the sampling, i.e. from the first storm sampled through the last storm sampled
- If artificial storms are used, identify the method and application rates of water and translate those rates into corresponding rainfall intensities
- Statement of certification signed by the proponent indicating that the protocol was followed

Additional considerations with inserts for drain inlets:

- Data showing the effect of accumulated litter and leaves on performance, flow capacities
- The point in the maintenance cycle that the field tests were run: i.e. were the units tested “fresh,” without prior field exposure or were they in the field for some time

Documentation of laboratory studies:

- Description of the composition of the test water
- The size distribution of TSS in the influent and effluent
- The test flow rates
- The performance at each flow rate
- Mass balance of influent, effluent, and collected sediment

Conclusions

The protocol offers a reasonable and defensible approach that provides rationale for the consideration of technologies that are not currently approved for use in new developments as well as for public projects. The protocol is most suitable for the maritime climate of the Pacific Northwest. It is anticipated that the protocol will change over time, particularly as the data base for approved technologies becomes more extensive and as we learn from its use. More performance data are needed for public domain technologies located in our region, in particular wet vaults and constructed wetlands for which there are currently no data.

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By Any Measure.. .

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The introduction of a diverse array of stormwater quality management tools in the last few years has created problems for the growing number of individuals and organizations who would like to compare the performance of these tools. Comparison is complicated by differences in treatment capacities, targeted pollutants, and treatment approaches. Several methods of evaluation have emerged in response to the need for verification of theoretical performance predictions: yet none of these "yardsticks" are appropriate in all situations and results from each are often not readily comparable to results from other measures.

Complicating the matter further is the confusion regarding what is being compared. In some cases, a technology will be compared with another technology. In other cases, the technology is compared to a performance standard. (Analogy: My maple syrup may be better than your maple syrup, but does that make it Grade A maple syrup?)

The confusion stemming from this is greater than meets the eye. For example, many specifiying engineers and hydrologists want to meet a performance standard of 80% TSS removal on an annual average basis. They go to guidance manuals and product manufacturers seeking something that will meet the standard. As the selection process develops, they grapple with cost, maintenance, the availability of land needed, and many other issues under the heading of "cost-effectiveness" for their clients. But by the time the selection has been made, it has become more a question of who has the better maple syrup rather than whether or not the selected product meets the standard. That is partly because 80% TSS removal on an average annual basis is virtually an impossible standard to achieve.

It is not the ***purpose*** of this paper to propose the adoption of one standard over another.

It ***is the purpose*** of this paper to review the merits of various measures of performance and, more importantly, to stress that any monitoring program that attempts to measure performance of a stormwater quality management system should begin with a consideration of how the observations will be reported.

Any monitoring program will consist of:

- Sampling
- Testing
- Reporting

Often, researchers start with the selection of samplers and procede with questions of deployment and maintenance of the samplers. Only when samples have been collected are the questions of testing, and eventually reporting, given much thought. We propose that the reporting aspect, even though it is "last" chronologically, should dictate how the testing and sampling are done. For example, if the report is considered most informative when its focus is the mass of pollutants removed, as is often the case, there is no need for samplers. To get those results usually requires only the very simple task of periodically measuring accumulations of precipitated sediments or floatable petroleum products (or other pollutants) and doing simple arithmetic calculations to determine the mass removed. We know of projects that went to the extraordinary effort that it takes to procure, set up, operate, and maintain automatic samplers to obtain influent and effluent concentrations, only to "back into" an estimate of the mass of pollutants removed by a convoluted set of "volume-times-concentration" calculations. This is a classic case of doing something the hard way, not to mention the very expensive way. So the first rule of thumb for any monitoring project is to ***decide first*** how to ***report the results.*** Then design the sampling and testing around the information that is to be reported.

In this paper, we will present the following four "measures" of performance from which to choose in making those decisions. We consider these measures to be the current "status quo of the art."

- Mass of pollutants removed
- Event mean concentration (EMC)
- Lines of Comparative Performance (Minton, et. al.)
- Plotting efficiency versus operating rate

First, we would like to discuss in some detail some of the broader issues involved in monitoring stormwater treatment systems and measuring and reporting on their performance.

Setting

The setting is nearly always in the field or in a laboratory. We feel that the many benefits of testing in a laboratory are generally underestimated by technical professionals and non-professionals alike. What we refer to as the setting tends to be pre-determined well before a study gets underway. Since the setting tends to influence the important decision of what performance measure is best, this cursory overview is provided for perspective.

Field testing

The drawback with field testing is that it cannot be replicated very well. Every site is different. Every storm is different. There are "wet years" and "dry years." There are seasonal variations that can produce easily treated heavy sediment loads in winter and spring; hard-to-treat loadings, such as pollen and grass clippings, in summer; and moderately treatable loadings (leaves etc.) in the fall. It is poor science to compare the results of a field test of any treatment system to the results of a test of the same system at a different time and place.

Still, field testing has tremendous appeal because the stormwater and the sediments are "real."

- Field testing of individual facilities is usually adopted to evaluate the facility's performance in comparison to a performance standard (such as 80% TSS removal) to see if it "measures up." This setting is the simplest and most common, and is adaptable to any of the measures. The treatment system can be set up to treat all runoff or it can bypass flows that exceed the treatment capacity.

- "Side-by-side" field testing of several different facilities is increasingly popular, at least in concept. But, to our knowledge, this approach has not yet been successfully implemented. A key element is the design of the "flow-splitter" that takes all of the runoff and "splits" it into an equivalent discharge to each treatment system. The easy part of the design of the flow-splitter is achieving equal flow rates of ***water*** to each of the facilities (and even this "easy part" is not always all that easy). The hard part is getting equal discharge of ***pollutants*** to each of the facilities.

Whether testing an individual system or multiple systems, researchers have the potential to learn something very basic and very important from field testing that has, to our knowledge, eluded researchers to date. That is the determination of an appropriate threshold for bypassing peak flows. Consider a site that is estimated by conventional runoff modeling to discharge stormwater runoff at a rate of 3 CFS in a 1 O-year storm. Consider further two proposals for treatment. One claims efficiency of 90% and a treatment capacity of 1 CFS. The other claims 80% and a treatment capacity of 3 CFS. Which treatment option should be selected? If the prevalent standard of 80% is in place, the "safe" choice would seem to be treating all runoff from a IO-year event with 80% efficiency. But what if price is a factor? Maybe the system with 1 CFS capacity costs less. Even at the same cost, would 90% efficient be preferable to 80%? And with that consideration comes the $64,000 question. Will the system that claims 90% efficiency with a capacity of just 1 CFS even meet the standard of 80% overall? How much of the pollutant load will bypass the system altogether?

Some proponents of small-flow/high-efficiency technologies have stated that 90% of all storms are less than 1 inch of total rainfall and, therefore, treating 90% of all rain at 90% efficiency will yield a net annual removal of 81%. This argument is fundamentally flawed. It assumes that the 90% of rain from small storms carries 90% of the pollutants. This is simply not the case. The rate of mobilization of virtually all pollutants depends on rainfall intensity, not depth of rain. Therefore, it is important to treat high-intensity flows resulting from the infrequent event, which tend to carry a disproportionately high pollutant load.

If 1 inch of rain falls in 24 hours, virtually any system that is reasonably proportioned, designed and, of course, maintained for the treatment of stormwater will do a good job. Efficiencies of TSS removal should be in the 90% range if the runoff is fairly dirty with silty-to-fine sandy sediments.

It is questionable, however, as to whether or not all of the runoff would be dirty if the rain that produced the runoff totaled 1 inch and fell over a 24-hour period. Intuitively, the "last flush" of such a storm would be very clean. But even the first flush may be very clean in comparison to what it would be if 1 inch of rain fell in 1 hour. This highly variable "dirtiness" gives rise to another interesting question when trying to measure efficiency. That is the question of how to account for the inevitable reduction in treatment efficiency when the water to be treated is clean in the first place. No treatment system can remove what is not there. So it has been argued that some accounting should be made for the fact that there is some lower limit to the physical treatment that can be provided. Minton's "Lines Of Comparative Performance" (see figure 2.) take this important consideration into account and are discussed later.

The "Double Whammy" of the "2-Month Storm"

Infrequent, high-intensity storms are important to the effective treatment of stormwater for two reasons:

- Over time, the higher intensity of less-frequent rainfalls, and the resulting higher stormwater runoff velocity, is what transports most of the sediment off of streets.

- The treatment facility is overloaded by the high flow of water that is transporting the sediment at the same time that most of the sediment is being transported to it.

Schueler and Shepp (1993) performed monthly observations documenting a random pattern of accumulation and loss of sediment in a study of 17 different oil/grit separators in Maryland. Overall, the losses of sediment "outnumbered" the accumulations. In other words, the observed systems lost previously accumulated sediments once every two months. We have inferred from their work that the "2-month storm" is a reasonable benchmark for stormwater treatment. To be "measurably" better than the poorly reputed conventional oil/grit separator, a system or a facility should be able to demonstrate, at a minimum, that it can continue to function in the 2-month storm. If a system is found to lose sediment in a 2-month storm, it should not be considered any better than conventional technology. Similarly, if a system needs a bypass to protect it from washing out in 2-month storms, it should be considered only marginally better than conventional oil/grit separators. Bearing in mind that high flows transport much of the total sediment, treatment systems should be able to handle more than ***the 2-month storm*** without bypass. Otherwise, much of the total sediment load may be discharged to the receiving waters that the system is supposed to protect.

Clearly the statements of the preceeding paragraph are more of a hypothesis than a statement of fact. One way to validate or invalidate the hypothesis is described in the following section on side-by-side testing in the field.

Side-By-Side Testing

Testing stormwater facilities "side-by-side" has recently become a very popular idea. The premise is that a well-run comparison of systems treating "the same stormwater and the same pollutants at the same rates of flow" will go a long way to reduce the tremendous "scatter" in the data that has been obtained to-date by testing individual systems at different sites. If two systems are evaluated at different sites, even if the study is carried out by the same researchers using the same protocol, the results will probably not be comparable. Every site is different, and from the point of view of stormwater treatment, differences that appear slight can actually be significant. We have observed a dozen systems installed on a single site (a large shopping mall parking lot) which were specified by the same engineer and installed by the same contractor at more or less the same time and, of course, subjected to the same weather. They exhibited decidedly different results when we measured sediment accumulations in the systems. The sediment depths ranged from a light dusting to accumulations of over two feet in less than a year.

So it is important in "side-by-side" testing that there be just one flow stream to the two (or more) systems being tested and that the flows be split, so that each system gets exactly the same rate of flow and the same pollutant concentration at all times.

The main benefit of "side-by-side" testing is that it can provide an answer to the question, posed earlier, of whether it is preferable to have, the arrangement should be as shown in Figure 1.

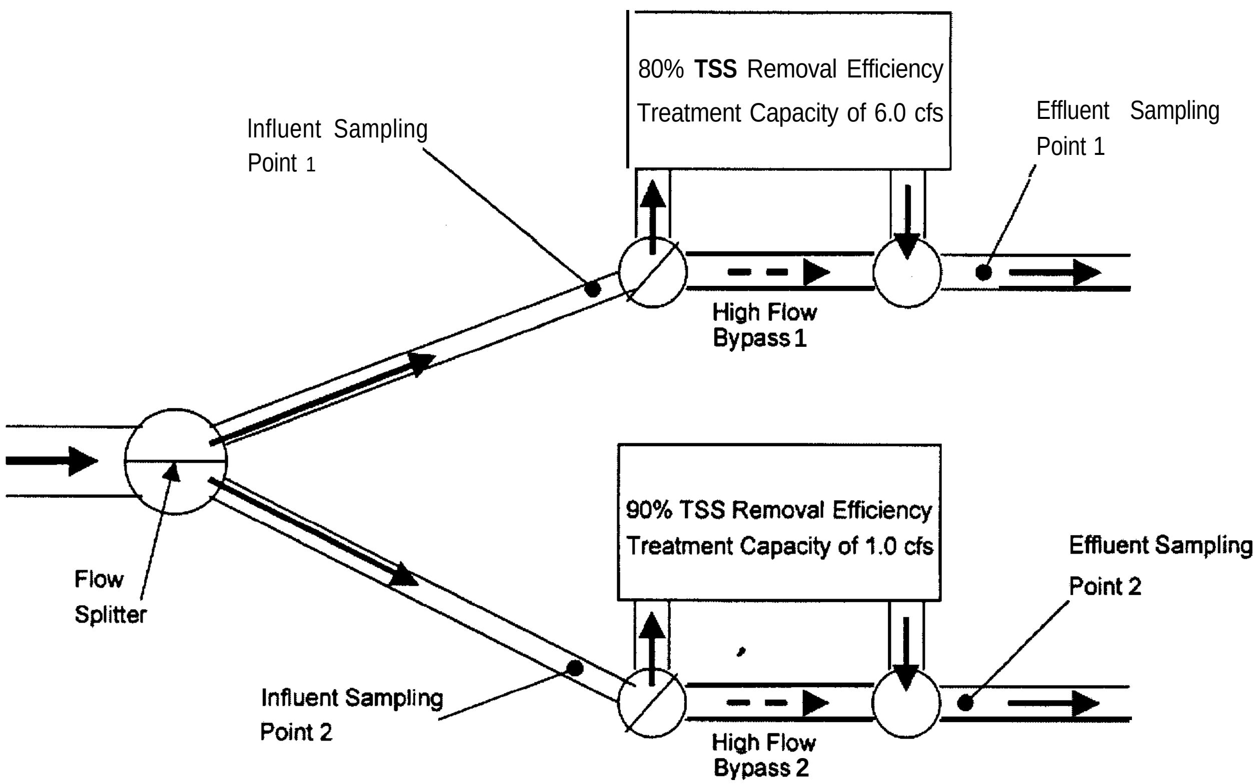

Figure 1. Recommended Arrangement For Side-by-Side Field Testing.

By sampling at points 1 and 2, the overall efficiency of the treatment system and bypass can be assessed objectively. Also, the question of "Which is the better system?" is answered. There are two shortcomings:

- Lack of repeatability. If one system gets 80% efficiency overall and the other gets 70% overall during one year of testing, there is no assurance whatsoever that either number will be repeated the next year. The test results should be regarded as indicative of performance. They are certainly not an assurance of performance over time. Such is the inconsistency, or "noisiness," of stormwater treatment data. A study like this should be conducted over a period of no less than two years. If the second year's results are reasonably close (in terms of statistical correlation) to the first, it can be considered complete. If not, it would be tempting to average all results. We feel that it would be poor science to do so, however. With the seasonal variability of stormwater pollutant loadings, one year's results will produce a single data point. A second year's results will produce a second data point. Many people seem to regard each storm result as a single data point, but as long as standards continue to be based on "average annual removal efficiencies," that is simply not the case.

- Variability with other sites. We have already mentioned the differences from one site to the next. The basic premise of side-by-side testing is to determine relative performance of two or more systems (i.e., which is best). As long as such a study is limited to this premise, the variability from one site to the next will not be a problem. But we know from experience that any "study," even the most cursory, tends to be overly generalized. We can only caution against doing so.

Laboratory Testing

Testing stormwatertreatment systems in a laboratory setting offers some very significant advantages over field testing.

- It is repeatable and demonstrable.
- It is more productive in the sense that decades of rainfall can be simulated in a matter of days.
- It is more economical in terms of labor, sampling equipment, and flow-metering equipment costs.

Laboratory testing achieves these benefits by controlling operating rates, particle sizes, and pollutant loading. When influent concentrations are very low, removal efficiency will be low; but for concentrations that are generally recognized as representative for stormwater, all concentrations tend to produce comparable removal efficiencies.

In the lab, a set of tests can be run using one particle size (at representative concentrations) at operating rates from zero to the system's capacity. At the conclusion of these tests, a curve can be drawn plotting efficiency versus operating rate on the y-axis and x-axis, respectively. Such a curve typically slopes downward to the right, reflecting reduced efficiency and higher operating rates. Any point along a constructed curve should be reasonably reproducible when using the same influent sediment load.

Subsequently, a whole family of other curves can be constructed using different particles. Also, to more closely simulate "typical" sediment, a graded sediment sample can be developed and tested in the same way.

Laboratory testing should not be considered the "last word" in documentation of a system's performance, but can be considered a "benchmark" which is very useful in comparing systems operating at flow rates up to their capacity. Some field testing, where it is feasible, should supplement the work in the lab and, as previously discussed, side-by-side field testing is the only way to determine the impacts of bypasses on different systems.

The Four Most Common Measures of Performance

1. Mass of Pollutants Removed

This is easily the simplest approach to stormwater treatment measurements in the field. By measuring the depths of sediment accumulations in the facility on a periodic basis, it becomes a simple arithmetic exercise to calculate the volume and mass of sediments removed by the system.

Additional information is made available by this measurement. It may be recalled, from our earlier discussion of the 2-month storm, that Schueler and Shepp used measurements of sediment accumulations to document the poor performance of conventional oil/grit separators.

Researchers should consider using the same approach for the newer technologies that have come along since their important work was published. The approach can be made even more informative by correlating observations to such things as activities in the drainage area (e.g., winter sanding, sweeping, a spill, etc.) or meteorological events such as observed rainfall intensities or precipitation depths.

2. Event Mean Concentration (EMC)

These are sometimes referred to as "flow-weighted" or "flow-based composite" samples. They are nearly always obtained using automatic samplers, a flow-meter and a flow totalizer that arithmetically converts the flow rate measured by the flow-meter to flow volume over time and keeps track of the volume.

The sampler receives a signal that causes it to take a sub-sample when a programmed volume of flow is measured. For example, one sub-sample might be taken every 200 cubic feet of flow through the system. Over the course of the storm, all sub-samples would be combined into one large sample container from which the concentration will be obtained that represents the flow- weighted average for the entire storm.

Without a flow meter, the samplers could be set up to take a "time-based composite" sample; i.e., to sample every 30 minutes. Flow-weighted samples are much more representative, as a simple example will show. Consider a volume of 1,000 gallons with a uniform concentration of 300 mg/l flowing at a uniform rate past the sampling point in 15 minutes, followed by half as much volume (500 gallons) with a 100 mg/l concentration flowing by in the next 15 minutes. The correct representation of the concentration would be calculated as:

$$\frac{(1{,}000\,x\,300)+(500\,x\,100)}{1{,}000\,+\,500}=223$$

Flow-weighted sampling will more accurately reflect this. For example, if the sampler were programmed to pull a sample every 500 gallons, then 2 samples at the higher concentration would be taken and just one at the lower concentration. The average concentration would be calculated as:

$$\frac{300+300+100}{3}=223$$

Time-based sampling would, if the programmed time interval were 15 minutes, take one sample with a concentration of 300 and another with a concentration of 100, and the average would be calculated as:

$$\frac{300+100}{2}=200$$

Automatic samplers that can take flow-based composites have become a very valuable tool for sanitary engineers measuring concentrations of pollutants in wastewater. We believe that they have been too quickly applied to stormwater monitoring without regard for some of the inherent differences. Waste streams have "highs and lows" of both flow rate and concentration, but they are not nearly as wide as the variability of stormwater, which can change from flow rates of zero to a deluge in a matter of minutes and concentrations that can also exhibit a minimum of zero. These "spikes" can cause very brief periods of negative efficiency if a system is prone to washing out (as stormwater systems were shown by Schueler and Shepp to do regularly). If a wash-out occurs, it is an important phenomenon to note, but the briefly elevated concentration in the effluent will be "composited" with the rest of the (presumably lower) effluent samples. This will reduce the "event-mean-concentration," but will not reveal that a washout has occurred. Noting washouts, and the flow rate that caused them, is a very important aspect of a stormwater monitoring program; but they are not likely to ever be revealed by EMC data.

The second drawback of EMC data is that when influent concentrations drop to very low levels that cannot be further reduced by physical treatment, the efficiency, as measured by EMC's, will be reduced. This tends to obscure the fact that higher efficiencies can be achieved when they need to be achieved; i.e., when influent concentrations are higher.

3. Minton's "Lines of Comparative Performance"

It is widely acknowledged that there is a lower limit to the capabilities of physical treatment systems for stormwater. This means that it is very unlikely that effluent concentrations would ever be zero. It also means that very low concentrations would not be significantly reduced.

Minton et. al. has proposed the following mathematical expression to describe this lower limit:

$$\frac{Influent - LowerLimit}{Influent}$$

If the lower limit is 20 mg/l, then a plot of this expression is that shown in figure 2.

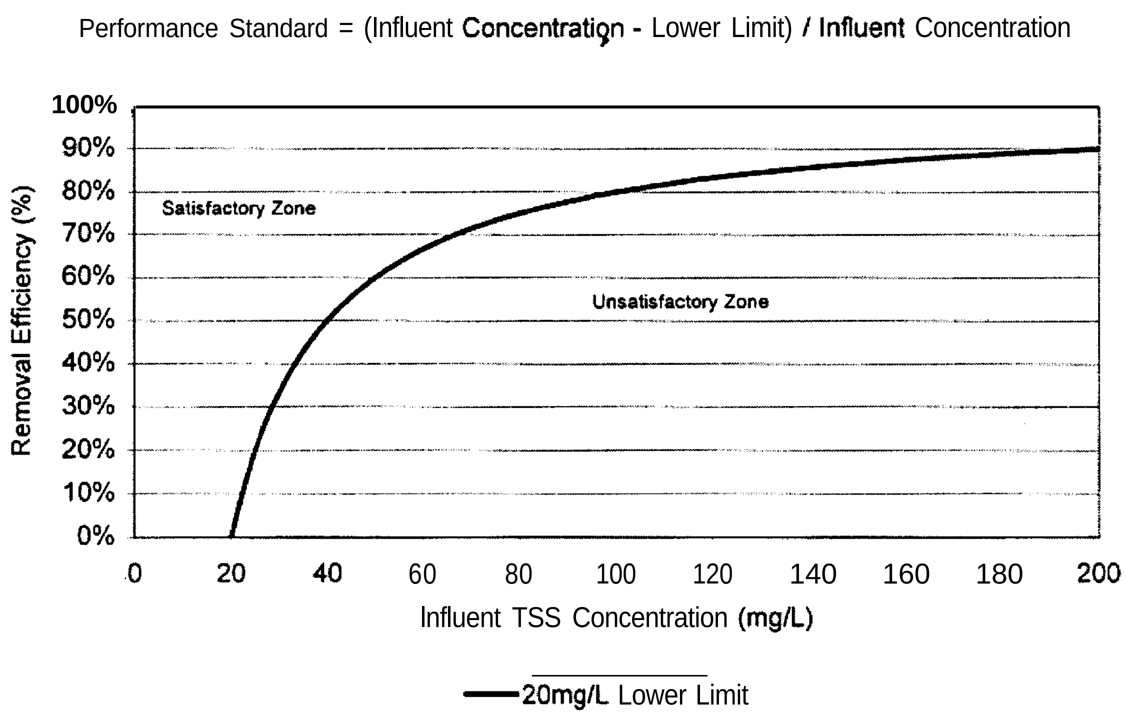

Figure 2. Line of Comparative Performance.

Plotting individual data points on such a graph can be very informative. Observed efficiencies above the line (designated a "line of comparative performance" by Minton) are considered satisfactory, while those below the line are unsatisfactory. Best of all, EMC's can be used without unfairly representing the efficiency. While the efficiency may be reduced by low influent concentrations, it may still be shown to be "satisfactory." More research will be needed to determine what is an appropriate lower-limit value to use in this approach.

4. Plotting efficiency vs. operating rate.

This approach was essentially described earlier under the heading of Laboratory Testing. By using discrete sediment particles in the laboratory, a family of curves such as those in Figure 3 can be developed.

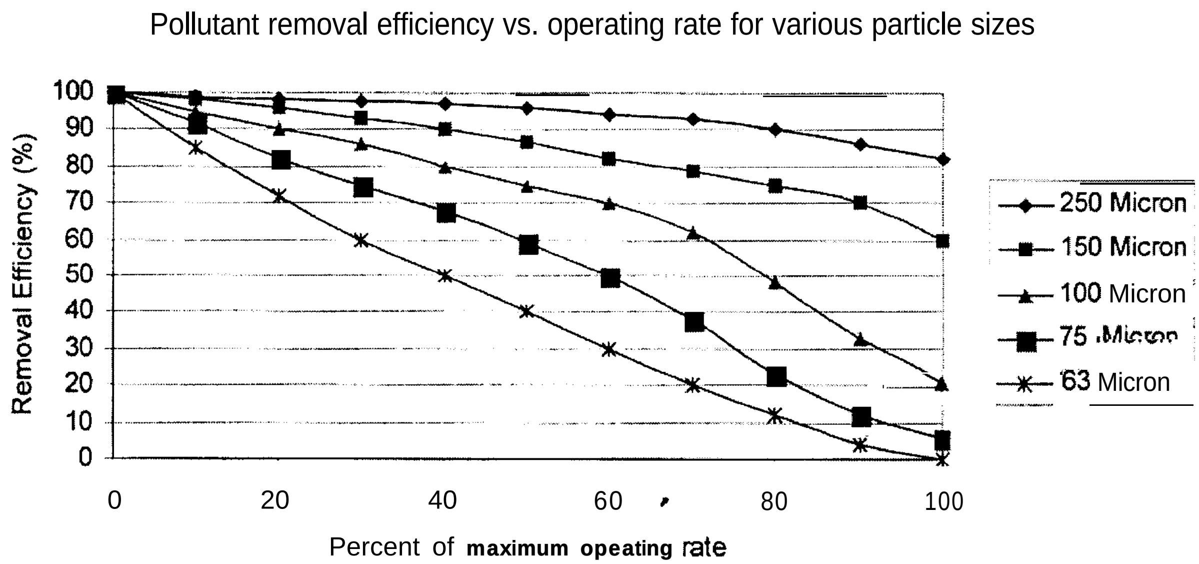

Figure 3. Removal Efficiency versus Operating Rate.

Field data is less likely to fit the relatively tight curves that can be generated in the lab. At the same operating rate, you may have vastly different influent concentrations, particle gradations, organic content, etc., depending on such factors as the time of the storm, anticedent dry period, and time of year. Removal efficiency is a function of all of these factors combined.

We feel that this performance measurement technique and presentation is the most informative. Its repeatability under controlled conditions makes it ideal for comparing one system to another. Certainly, if one system's performance curve on 100-micron particles, for example, is higher at all flow rates than another, it could reasonably be judged to be the higher efficiency system. If the curves are similar at low rates of operation, but either system drops down to zero efficiency at some higher flow rate, that flow rate should, of course, be considered the peak capacity for that system. This approach cannot show compliance with any standard for a stated percentage of TSS removal on an annual average basis.

Conclusion

To our knowledge, these four measures represent all of the techniques that have been used to measure the effectiveness of various stormwater treatment systems.

Measuring sediment accumulations in the field provides a good deal of useful information on mass removals and the ability to retain (or fail to retain) previously captured pollutants during periods of high flow. This approach costs very little to implement.

Event-mean-concentrations are the most widely accepted measure, but may not report all efficiencies and will almost certainly allow any failures to go undetected. This approach requires the use of automatic samplers at considerable cost, in terms of both time and money.

Minton's Lines of Comparative Efficiency are more fair to the treatment system because they account for the inability of any system to remove pollutants that are not present (or present in very low concentrations). If EMC data is collected to plot against the lines, then there are the same drawbacks of cost and automatic samplers allowing failures to go undetected. Both of those drawbacks can be overcome, but only with a very dedicated effort to take samples manually. Taking manual samples throughout the duration of all storms is very time-consuming and unpleasant work. For that reason, it is almost never done.

Plotting efficiency versus operating rate, whether in the field or in the laboratory, is arguably the most informative approach. In the field, automatic samplers are used (with individual samples in individual bottles and not cornposited), so there are those costs to consider. In the lab, samplers are needed but the construction of a model treatment facility, and the pumps and tanks to handle the required flow rates and volumes of water, will more than offset that cost saving.

Since none of these measures provides an ironclad confirmation that the widely prevalent standard of 80% TSS removal is being met, we submit that a different standard should be adopted by stormwater management jurisdictions.

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Stormceptor Hydrology and Non-point Source Pollution Removal Estimates

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Abstract

A model has been developed to estimate total suspended solids (TSS) removal using Stormceptor, an oil/sediment separator. The model was based on a commonly used, continuous simulation model United States Environmental Protection Agency Stormwater Management Model (USEPA SWMM) for hydrological processes. The suspended solids loading was estimated using build-up and wash-off equations. The solids were assumed to be distributed into five particle sizes for settling calculations. Simulations were conducted using various assumptions of loading and settling velocities to determine the sensitivity of the model to assumptions. Simulations were also conducted for a diverse range of geographic areas to determine the sensitivity of the TSS removal rates to regional hydrology. The model was sensitive to the selection of settling velocities and pollutant loading. The model was less sensitive to changes in hydrology, although significant changes in hydrology did impact TSS removal estimates.

Keywords: Stormwater; suspended solids; model; hydrology; Stormceptor, separator

Introduction

The Stormceptor is a mechanical water quality separator designed to remove oil and sediment from stormwater. A key feature of the design is an internal high flow by-pass to prevent scouring and re-suspension of previously trapped pollutants. Since the separator is based on treating "the everyday storm," the effectiveness of the separator is dependent on the distribution of pollution in stormwater and the frequency and magnitude of stormwater flows throughout the year.

In 1995, sizing guidelines were derived for the Stormceptor based on field monitoring of sludge accumulation over time in Toronto, Ontario, Canada. The accumulation data were used to derive estimates of annual total suspended solids (TSS) removal. Two key assumptions were made in the 1995 analysis to estimate TSS removal: (1) a TSS loading rate of 185 mg/l based on the USEPA's Nationwide Urban Runoff Program (NURP) median (U.S. Environmental Protection Agency, 1983), and (2) a sludge water content of 75% water. Actual Toronto rainfall data, combined with the NURP TSS concentration, provided estimates of annual TSS loading. Figure 1 shows the performance relationship derived from the Toronto monitoring, which forms the basis for the existing sizing guidelines.

Toronto rainfall time-series data (5 minute timestep) were input to a continuous hydrologic simulation model (SWMM Version 4.3) to determine the percentage of annual runoff treated based on the sizing criteria shown in Figure 1. The

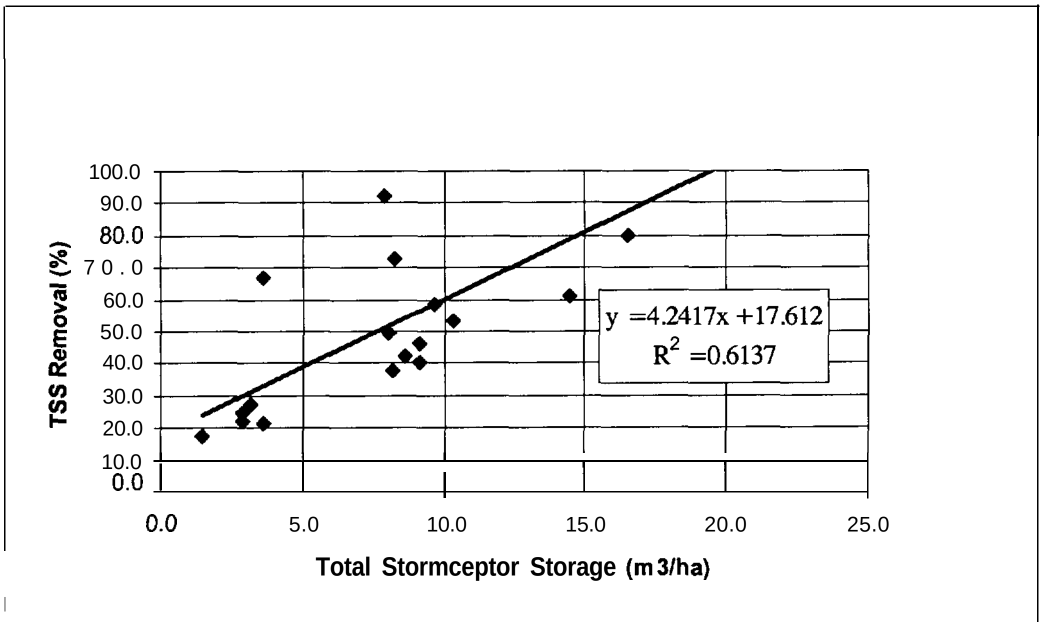

Figure 1. TSS Removal versus Stormceptor Total Storage (Toronto, 1995).

analysis of Toronto rainfall indicated that 80% - 90% of the annual runoff would be treated if the Stormceptor were sized according to these 1995 guidelines. This study was initiated to address concerns about the applicability of the Toronto-based sizing criteria to meteorological conditions in other regions.

Methodology

A computer simulation model was developed based on USEPA's SWMM Version 4.3. Solids build-up, wash-off, and settling calculations were added to the hydrology code to estimate suspended solids capture by the Stormceptor.

The model accommodates the use of either an EMC (event mean concentration) or build-up/wash-off calculations to estimate suspended solids loads. The build-up/wash-off model is more theoretically and physically correct. The EMC method has been shown to provide reasonable estimates of total solids loads (Charbeneau and Barrett, 1998) alone, if the distribution of the load is not important.

The distribution of pollutant load is important for measures that incorporate a high-flow by-pass (commonly known as "first flush" measures). Accordingly, preference is given to the build-up/wash-off calculations to correctly distribute the pollutant load with flow, recognizing the need to optimize the sizing of small-site stormwater quality measures.

In the model, solids build-up and wash-off are both approximated using an exponential distribution. The distribution of solids build-up is a function of antecedent dry days according to Equation 1 (Sartor and Boyd, 1972).

$$P_t = P_i + (PA - P_i)(1 - e^{-kt}) \qquad (1)$$

Where: P_t = solids accumulation up to day t (kg)
P = maximum solids build-up (2.4 kg/ha)
A = drainage area (ha)
P_i = initial solids load on the surface (not washed off from the previous storm) (kg)
k = exponential build-up factor (0.4) (days^{-1})
t = antecedent dry days

The maximum solids build-up (P) load was adjusted to provide similar long-term solids loading rates (124 mg/l) when compared to the EMC method. An exponential build-up factor (k) of 0.4 was used based on previous literature (SWMM 4.3 Users Manual). A k-value of 0.4 translates into 90% of the maximum solids build-up occurring after 5.66 days. Once the pollutant build-up reaches the 2.4 kg/ha limit, additional build-up is not allowed (assumed to be wind re-suspended/driven off the surface). Wash-off is estimated using Equation 2.

$$P_t = P_i e^{-kV} \tag{2}$$

Where:
Pt = solids remaining on the surface at day t (kg)
Pi = initial solids load (from equation 1) (kg)
k = exponential decay factor (0.2) (mm-')
V = volume of accumulated runoff from the surface (mm)

The exponential decay factor (k) of 0.2 was based on a review of previous literature that indicates k-values range from 0.03 to 0.55 (Alley, 1981; Charbeneau and Barrett, 1998).

Charbeneau and Barrett (1998) found that the simple wash-off model adequately described observed solids wash-off in Austin, Texas. Other researchers have cited that the wash-off Equation (2) is reasonable for fine material but may not be reasonable for larger solids that require a high rainfall intensity for mobilization (Metcalf and Eddy, 1991; Ball and Abustan, 1995). The SWMM model treats wash-off as a function of the runoff rate to account for mobilization. This correction is applied indiscriminately to the entire solids load and does not account for the variation in wash-off rate with particle size. If an "availability" factor is applied to all particle sizes uniformly, the model will underestimate the wash-off of solids with increasing runoff volume if the majority of particles are fine in size. The approach taken in this study was to use an availability factor for particles 400 μm in size or larger. Smaller particles follow the simple wash-off estimates given by Equation 2. The larger particles (≥ 400 μm) require greater runoff intensities to induce wash-off according to the availability factor provided in Equation 3.

$$A = 0.057 + 0.04(r)^{1.1} \tag{3}$$

Where:
A = availability factor
r = runoff rate (mm/h)

Equation 3 is based on research by Novotny and Chesters (1997). The runoff rate is used instead of rainfall intensity, recognizing that the wash-off will lag the rainfall based on the time of concentration. The availability factor varies each timestep and is only applied to the runoff volume for that timestep, as dictated in Equation 4. The availabilty factor has an upper limit of 1.

$$V = V_i + A(V_t) \tag{4}$$

Where:
V = accumulated runoff volume used in Equation 2 (mm)
V_i = accumulated runoff volume prior to current timestep (mm)
A = availability factor (equals 1 for particles smaller than 400 μm)
V_t = runoff volume for current timestep (mm)

The correction in Equation 4 effectively re-defines the accumulated runoff volume to be the runoff volume sufficient to mobilize the particles. This methodology requires more accounting in the model but provides a more physically correct wash-off model.

The separator was treated as a completely stirred tank reactor (CSTR). Alterations to the concentration of solids in the separator will vary according to Equation 5 (Tchobanoglous and Schroeder, 1987).

$$C'V = QC_i - QC, - r_c V \tag{5}$$

Where C' = the change in concentration of solids in the tank with time (kg/m^3s)
Q = flow rate through the tank (m^3/s)
C_i = solids concentration in the influent to the tank (kg/m^3)
C_t = solids concentration in the tank (kg/m^3)
V = tank volume (m^3)
r_c = reduction in solids in the tank (kg/m^3s)

For gravity settling devices r_c can be estimated using Equation 6.

$$r_c = V_sC/D \tag{6}$$

Where r_c = reduction in solids in the tank (kg/m^3s)
Vs = settling velocity of solids (m/s)
D = depth of tank (m)
C = concentration of solids in the tank (kg/m^3)

Substituting Equation 6 into Equation 5, solving the first-order differential equation and integrating provides the general form of the non-steady state solution (Equation 7) for the concentration in the tank at time t.

$$C = QC_i/(V(V_s/D + Q/V))(1 - e^{-(Vs/D + Q/V)t}) + C_te^{-(Vs/D + Q/V)t} \tag{7}$$

Where C = concentration in the tank at time t (kg/m^3)
C_i = concentration in the flow influent to the tank (kg/m^3)
C_t = concentration in the tank at the beginning of the timestep (kg/m^3)
Q = flow rate through the tank (m^3/s)
V = volume of water in the tank (m^3)
V_s = suspended solids settling velocity (m/s)
D = tank depth
t = time

Equation 7 was used to estimate the suspended solids concentration in the tank, and in the discharge from the tank each timestep. Equation 7 assumes the suspended solids are completely mixed within the tank volume.

During periods without flow (inter-event periods) the solids are not assumed completely mixed at the beginning of each timestep and the depth of suspended solids in the separator decreases each timestep until all of the solids are removed or there are subsequent flows into the separator. The concentration of solids in the tank during periods without flow was calculated using Equation 8.

$$C = C_t(1 - V_st/D) \tag{8}$$

Where: C = solids concentration in the tank (kg/m^3)
C_t = initial solids concentration in the tank at the beginning of the timestep (kg/m^3)
V_s = settling velocity (m/s)
t = timestep (s)
D = depth of solids in the separator (m)

The depth of solids (D) in the separator in Equation 8 decreases each timestep based on the settling velocity until all of the solids are removed or there are subsequent inflows to the tank.

The model can be used with either hourly or 15 minute rainfall data. Fifteen minute data are preferred, recognizing that the Stormceptor is only applicable for small drainage areas. Small drainage areas have short times of concentration and require data with a suitable timestep. Internally, the model performs calculations with a 5 minute timestep.

The choice of particle size distribution and settling velocities is a key part of the modeling exercise. Different settling velocities can be applied to the same particle size distribution, based on the specific gravity of the particles or to account for the effect of non-ideal settling or flocculation on settling. In this study, a typical stormwater particle size distribution (USEPA, 1983) was used for analysis (Table 1). The distribution given in Table 1 is commonly accepted by most regulatory agencies in North America.

The model allows the user to alter the percentages of each size based on site-specific conditions, if required. In most areas, it is anticipated that the particle size distribution will not vary significantly since it is primarily related to vehicle wear and atmospheric deposition. There may be certain instances, however, where the native soils contribute loading and the default distribution needs to be altered. The default percentages were used in our study.

Table 1. USEPA Default Particle Size Distribution

Particle Size (pm)	% by Mass
20	20
60	20
130	20
400	20
4000	20

Settling velocities were then assessed for each of the particle sizes provided in Table 1. Settling velocities were either calculated or based on empirical literature (USEPA, 1983). The calculation of settling velocities for small particles follows Stokes' law (Equation 9) since the Reynolds number (Equation 10) is less than 0.3.

$$Vs = g\ (p, - p_w)d^2/18u \qquad (9)$$

Where
Vs = settling velocity for particle diameter d (m/s)
g = gravity (m/s^2)
p_s = density of particles (kg/m^3)
p_w = density of water (kg/m^3)
d = particle diameter (m)
u = viscosity of water (kg/ms)

$$N_R = V_s d p_w/u \qquad (10)$$

Where
N_R = Reynolds number
Vs = settling velocity for particle diameter d (m/s)
p_w = density of water (kg/m^3)
d = particle diameter (m)
u = viscosity of water (kg/ms)

If the Reynolds number is greater than 0.3, drag on the particles reduces the settling velocity. An iterative solution was used (solving for the Reynolds number, drag coefficient, and settling velocity until changes in the settling velocity were insignificant) for particle sizes with the Reynolds numbers. The drag coefficient is given by Equation 11, and the settling velocity is calculated by Equation 12.

$$C_D = 24/N, +3/(N_R 0.5) + 0.34 \qquad (11)$$

Where
C_D = drag coefficient
N_R = Reynolds number

$$Vs = (4g(p_s - p_w)d/(3C_D p_w))^{0.5} \qquad (12)$$

Where Vs = settling velocity for particle diameter d (m/s)
g = gravity (m/s^2)
p_s = density of particles (kg/m^3)
p_w = density of water (kg/m^3)
d = particle diameter (m)
C_D = drag coefficient

Table 2 provides a comparison of the settling velocities used in this study.

Table 2. Discrete Particle Size Settling Velocities (mm/s)

Particle Size (μm)	S.G. = 1.3 calculated	S.G. = 1.8 calculated	S.G. = 2.65 calculated	USEPA (1983) empirical
20	0.07	0.17	0.36	0.00254
60	0.59	1.57	3.23	0.02540
130	2.50	5.70	11.20	0.12700
400	16.00	37.00	65.00	0.59267
4000	180.00	300.00	450.00	5.50330

S.G. = Specific Gravity

The settling velocities that are based on the empirical USEPA data are 65 to 150 times smaller than the settling velocities based on a specific gravity of 2.65. A specific gravity of 2.65 is commonly associated with sand-size particles whereas the fines in stormwater are commonly associated with a lower specific gravity. The use of a higher specific gravity may be justified, however, if the values are considered representative of the settling velocities of fines in a flocculated or coagulated state. Research indicates that there is a high potential for coagulation amongst particles (Ball and Abustan, 1995) which will increase settling velocities and TSS removal rates. Furthermore, historical settling velocity calculations have been based on discrete particle methodologies (vertical settling column tests) that do not account for potential coagulation. Coagulation would effectively offset the settling velocity columns in Table 2 (i.e., discrete settling velocity for 60 μm represents coagulated 20 μm particle size).

Numerous field tests on the Stormceptor (Labatiuk, 1996; Henry et al., 1999; Bryant, 1995) have indicated a high percentage of fines in the Stormceptor. This empirical evidence lends credence to the coagulated settling theory, indicating that the USEPA discrete particle settling velocities may underestimate actual TSS removal rates. Settling velocities based on a specific gravity of 1.8 were chosen in this study as the default or benchmark selection. The solids loading was segmented into the particle size distribution and the concentration of solids in each particle size was tracked individually during the settling calculations.

Meteorological Data

Rainfall data from the City of Toronto (5 minute timestep, 0.25 mm resolution, 10 years record, 1987-1996) was agglomerated into 15 minute data for use with the model. Fifteen minute data were obtained for the entire U.S.A. from Earthlnfo on CD ROM. Stations were selected based on location, period of record, data resolution and completeness within the period of record. Data were also obtained from CSR Humes for various stations throughout Australia. The rainfall data were converted into National Climatic Data Center (NCDC) format for input to SWMM.

Fifteen minute data were utilized, recognizing the small time of concentration that would typically be encountered in most Stormceptor applications. Simulations were also conducted using hourly data to determine the sensitivity of the results to the precipitation timestep. Numerous hourly stations were available on the Earthlnfo CD for this purpose. The model uses a 5 minute timestep at all times regardless of the rainfall timestep.

Modeling Parameters

SWMM models catchments and conveyance systems based on input rain, temperature, wind speed, and evaporation data. Only rain data were used in these analyses. The default SWMM daily evaporation values (2.5 mm/day) were used. Evaporation data will not be important in this analysis since the catchment area is small (c 10 ha) and has minimal depression storage. The Horton equation was chosen for infiltration. The method of infiltration chosen is unimportant due to the small amount of pervious area (1%). Table 3 provides a list of the parameters used in the SWMM model.

Table 3. SWMM Area Parameters

Area - ha (ac)	variable
Imperviousness	99%
Width - m (ft)	variable
Slope	2%
Impervious Depression Storage - mm (in.)	4.7 (0.19)
Pervious Depression Storage - mm (in.)	0.5 (0.02)
Impervious Mannings n	0.015
Pervious Mannings n	0.25
Maximum Infiltration Rate - mm/h (in/hr)	62.5 (2.46)
Minimum Infiltration Rate - mm/h (in/hr)	10 (0.39)
Decay Rate of Infiltration (s^{-1})	0.00055

The width of catchment was assumed to be equal to twice the square root of the area.

Results

EMC versus Build-up/Wash-off

The suspended solids removal results based on the build-up/wash-off model were compared to those based on an EMC of 124 mg/l (USEPA, 1983) to demonstrate the sensitivity of the model to the different solids loading approaches. The use of an EMC assumes an equal concentration of suspended solids in all of the stormwater that is conveyed to the Stormceptor.

Figure 2 shows a comparison of results using an event mean concentration loading and build-up/wash-off loading, given the default particle size distribution and settling velocities based on a specific gravity of 1.8.

The results in Figure 2 show that the TSS removal rates using the EMC approach are lower by 14% when compared to the build-up/wash-off method even though the total loads are similar. This is expected due to the by-pass nature of the Stormceptor. The estimated TSS removals for the existing (1995) sizing guidelines, which are based on an early field study, are lower than both the EMC and build-up/wash-off estimates for low values (50% TSS removal) of separator storage/drainage area and are higher than the other estimates for larger values of separator storage/drainage area (80% TSS removal).

The range of TSS removal values based on computer modeling is smaller than the empirical TSS removal rates. Doubling the size of unit for the same area results in an increase of 30% for TSS removal, based on the current sizing guidelines, whereas the increase in performance based on the modeling is less dramatic (a 5% to 10% increase in TSS performance). This finding indicates that the modeling results will be less sensitive to changes in the model size for any given drainage area.

Selection of Settling Velocities

A comparison was made regarding the choice of settling velocities using Toronto rainfall data and the build-up/wash-off TSS generation methodology. Figure 3 provides the results of this analysis. The TSS removal estimates using the USEPA settling velocities are an average of 20% lower than the original TSS removal estimates, 29% lower than the estimates using the SG=1.3 velocities, and 39% lower than the estimates using the SG=2.65 velocities. These results indicate that the TSS removal performance results are very sensitive to the selection of settling velocities.

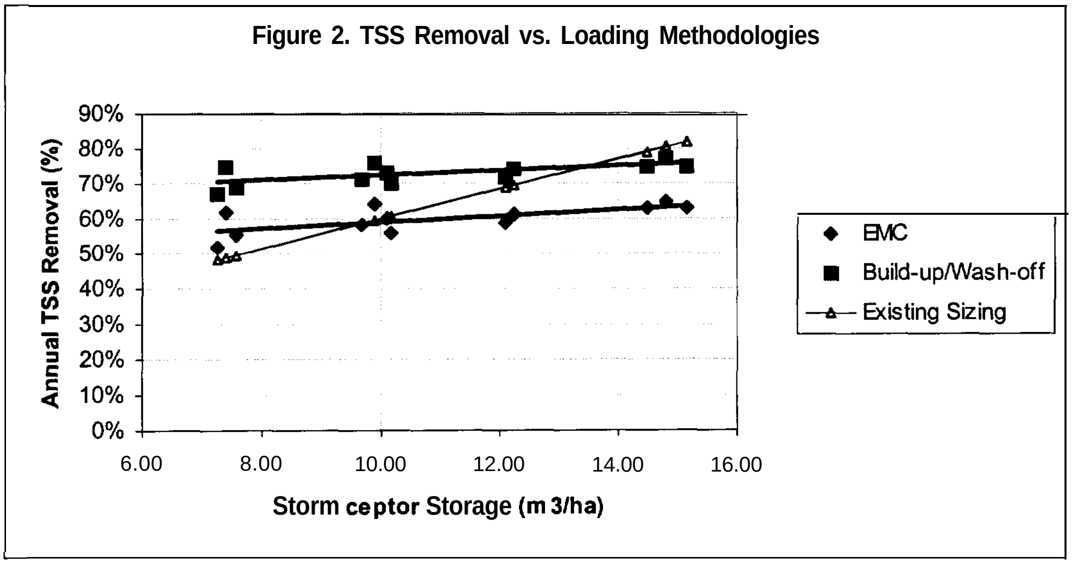

Figure 2. TSS Removal vs. Loading Methodologies.

Annual Flo w Treatment

Numerous regulatory agencies design stormwater quality measures using a "design" event. The design event used generally ranges from the 25 mm storm, or annual storm, to the 25-year storm. The modified SWMM program was used to calculate the percentage of annual runoff that would be treated (not by-passed) with different by-pass flow rates. This analysis was conducted using the Toronto rainfall for a drainage area of 2.25 ha. Figure 4 shows that the volume of runoff that is treated prior to by-pass quickly becomes asymptotic with increasing treatment flow rate. A device that treats 30 Us prior to by-pass would treat approximately 80% of the annual runoff. A device that treats 70 L/s (over 2x higher flow rate) only treats 10% more runoff (90%). Although the relationship between conveyance (% of annual runoff treated) and TSS removal is non-linear, Figure 4 shows that high-rate treatment devices are not required for small drainage areas.

The relationship provided in Figure 4 will vary with local meteorological conditions and is inherently accounted for in the TSS removal modeling.

Regional TSS Removal Performance Analysis

The model was used to compare results from different areas in North America and Australia to determine the effect of regional hydrology on TSS removal performance. All analyses were conducted using 15 minute rainfall data and based on the TSS build-up and washoff model and settling velocities for a specific gravity of 1.8.

Table 4 shows the results for various sized Stormceptors with a 2 ha drainage area. The locations of stations listed in Table 4 were selected to cover a wide geographic area, provide rainfall on a 15 minute timestep with a 0.25 mm resolution, and provide results representative of large nearby cities. Most data from city airports are recorded hourly, and therefore were not included in the comparison. The results in Table 4 are plotted in order of decreasing performance expectations in Figure 5.

Of the 16 stations analyzed, 12 stations provided TSS removal estimates within ±5% of the Toronto values.

Although the majority of stations provided similar TSS removal estimates, there were areas with significant differences. The performance estimates were lowest for the southeastern United States. This area is well know for its intense seasonal rainfall distribution. Figure 5 indicates that the TSS removal rates may vary up to 20% under different hydrological conditions on the same land use/site conditions. The use of local or regional rainfall data is therefore appropriate for design purposes.

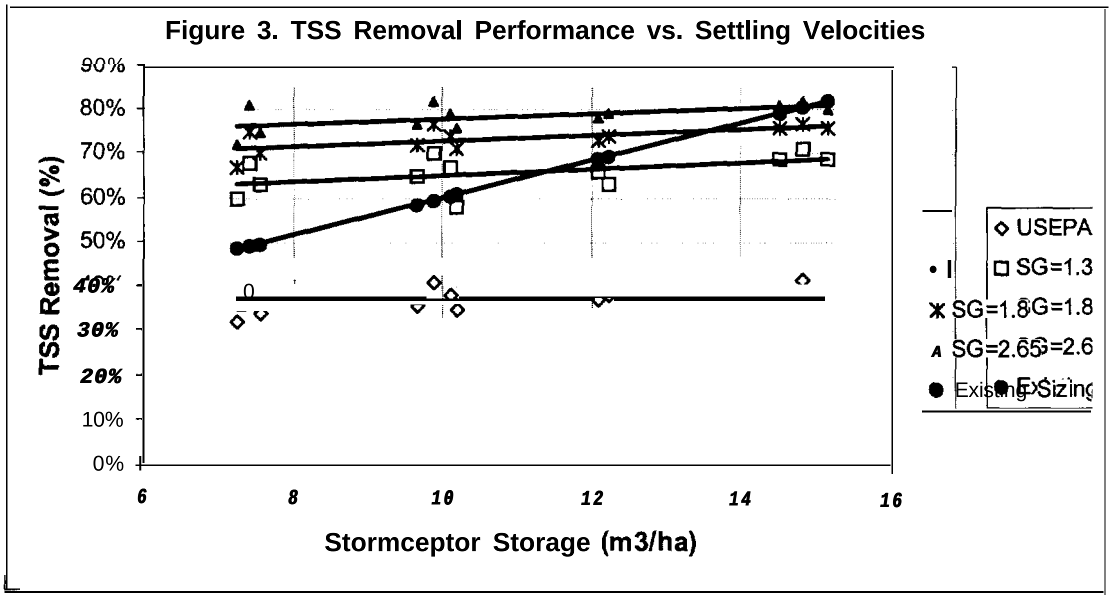

Figure 3. TSS Removal Performance vs. Settling Velocities.

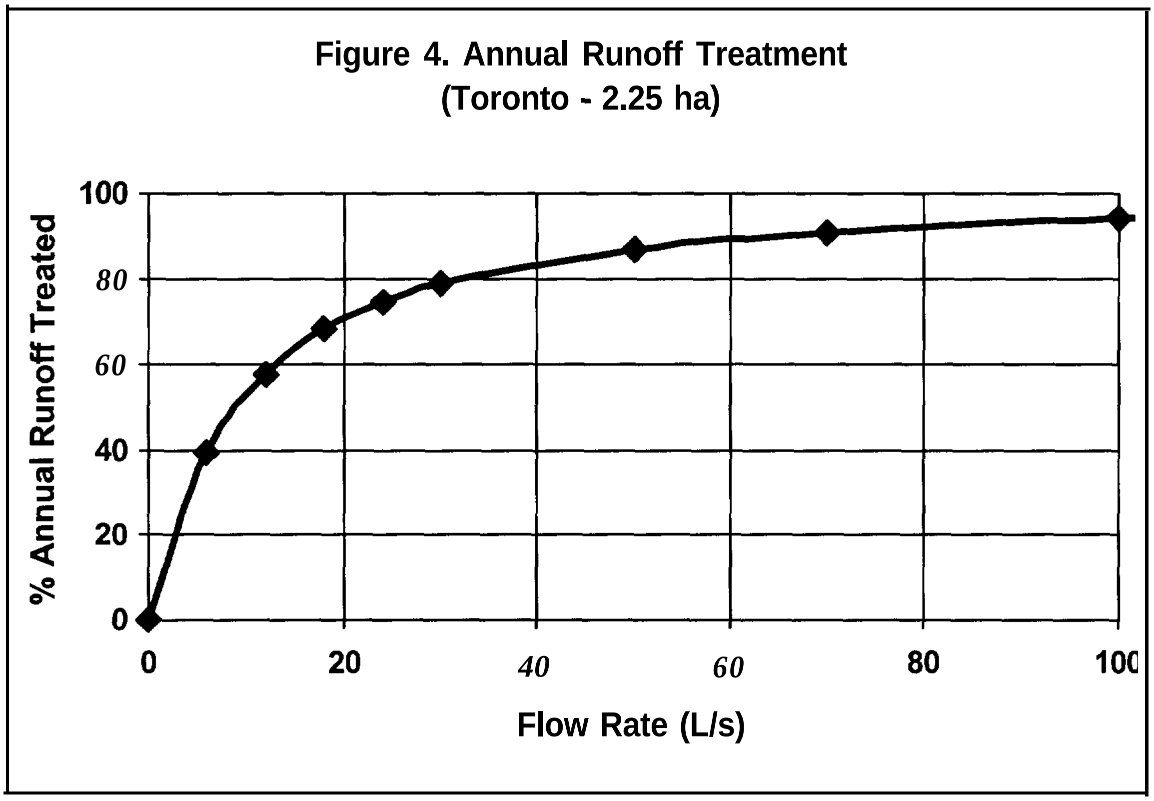

Figure 4. Annual Runoff Treatment.

Table 4. Regional Comparison of TSS Removal Performance (2ha)

State/ Province	Location	Stormceptor Model (CDNIUSA)					
		300/ 450	750J 900	1500/ 1800	3000/ 3600	5000/ 6000	6000/ 7200
Colorado	Fort Collins	49%	63%	65%	71%	76%	79%
Alberta	Calgary Forest	48%	63%	65%	71%	76%	79%
British Columbia	Vancouver	48%	65%	66%	71%	76%	78%
California	Davis	44%	61%	63%	69%	74%	77%
Massachusetts	East Brimfield Lake	43%	59%	61%	67%	73%	75%
Ontario	Toronto	43%	58%	60%	66%	72%	75%
New South Wales	Sydney	42%	57%	59%	66%	72%	76%
New York	Rhinebeck	41%	57%	59%	65%	71%	74%
North Carolina	Cataloochee	41%	56%	58%	64%	71%	74%
Queensland	Brisbane	41%	55%	57%	64%	71%	74%
Minnesota	Le Sueur	41%	56%	57%	84%	70%	74%
California	Orange County	39%	57%	59%	65%	71%	74%
Maryland	College Park	37%	53%	54%	61%	67%	70%
Missouri	Miller	34%	50%	51%	59%	65%	69%
Florida	St. Lucie New Lock	30%	43%	44%	52%	59%	64%
Texas	Houston Addicks	27%	41%	42%	49%	57%	61%

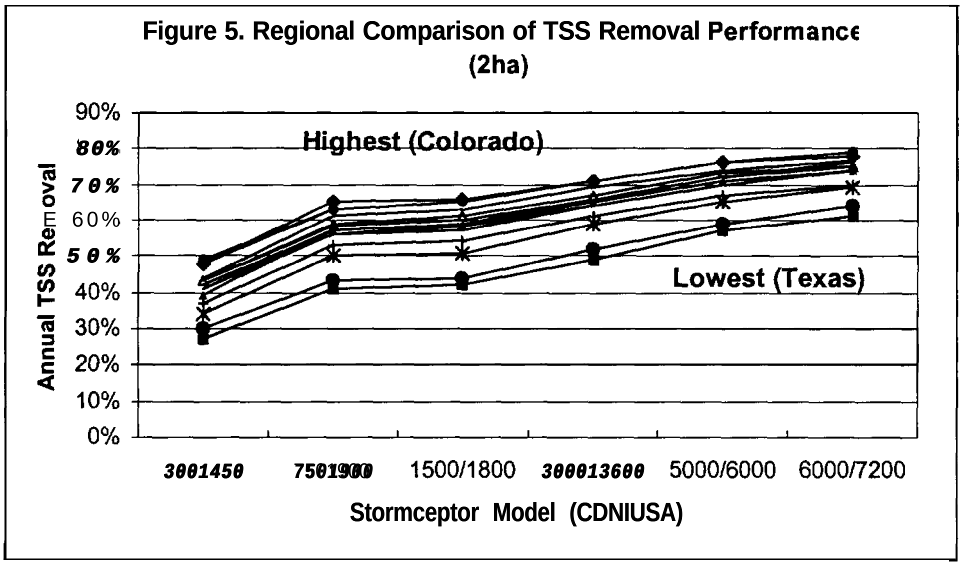

Figure 5. Regional Comparison of TSS Removal Performance

Rainfall Timestep

An analysis was conducted to determine the sensitivity of the model to changes in rainfall resolution. Results based on hourly rainfall data (0.25 mm resolution) were compared to those based on 15 minute rainfall data, to determine the impact of using the hourly data. Hourly data are more readily available than 15 minute data and most large cities have airports that collect rainfall on an hourly basis.

The model reads the hourly data as rainfall that falls during the first fifteen minute timestep of each hour. This will produce higher intensities since the rain is not distributed correctly over the entire hour. The greater intensity is compensated for, however, by the completeness of the hourly records which translates into a greater number of small rainfall values.

Four areas were analyzed (Rockville, Maryland; Boston, Massachusetts; Miami, Florida; and Houston, Texas). The results of this analysis (Figure 6) indicate that the use of hourly data does not significantly alter the TSS removal estimates for units that are designed to remove over 40% of the annual TSS load. Greater discrepancies can be expected at large ratios of drainage area to separator storage.

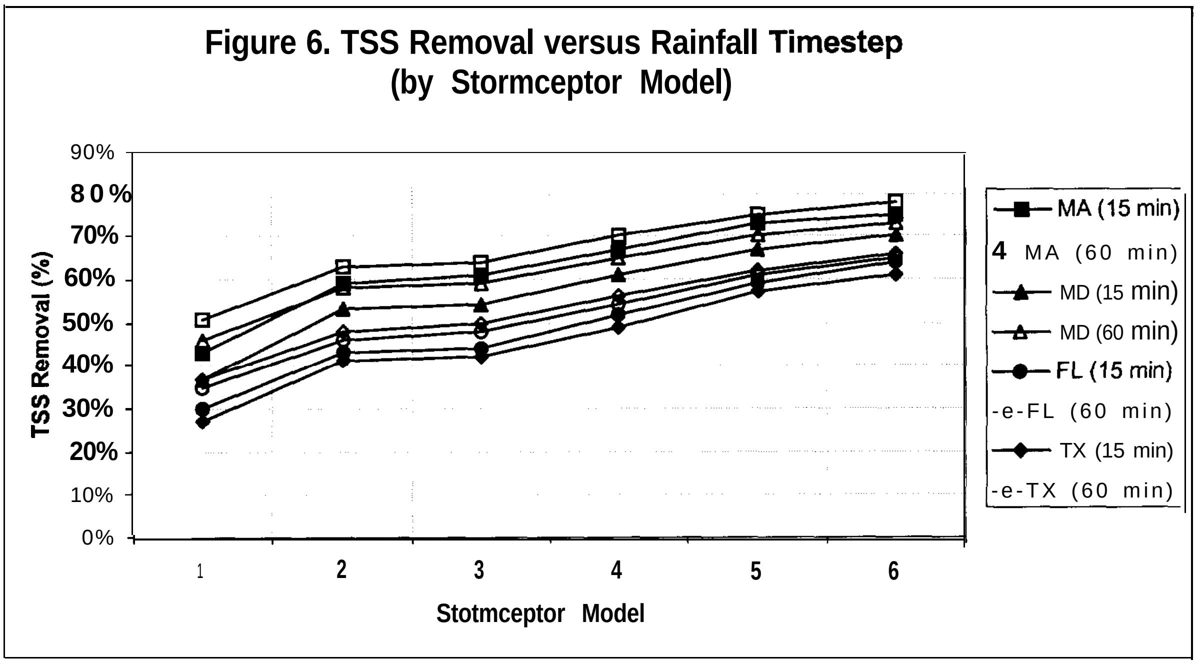

Figure 6. *TSS* Removal vs. Rainfall Timestep (by Stormceptor Model).

Conclusions

The TSS removal results were sensitive to the selection of settling velocities for the specified particle distribution. Differences in TSS removal of up to 40% were obtained, depending on the settling velocities that were evaluated.

Results were also affected by the TSS loading method. The use of an EMC underestimated TSS removal performance by approximately 15%, when compared to using the build-up and wash-off equations. This difference is expected since the EMC method increases the load that is by-passed and provides higher loads during higher treated flow rates when the detention time, and hence settling effectiveness of the unit, is reduced.

The model indicates that high percentages of the annual runoff can be treated with low-flow treatment devices such as the Stormceptor. The model also predicts that the TSS removal performance is less sensitive to the size of separator than observed from previous field studies.

Regional hydrology affected the TSS removal estimates provided by the model. Although differences of up to 20% were observed, significant hydrological differences between the sites were needed to obtain this variance. Most of the rainfall station locations tested provided TSS removal estimates similar to those of Toronto, where the original sizing guidelines were developed.

Testing the model with different rainfall timesteps (15 minute versus hourly) indicated that hourly rainfall records can provide an adequate estimation of performance if the rainfall is collected at adequate resolution (0.25 mm increments).

The modeling indicated that significant TSS removal rates can be achieved using small infrastructure control measures if the drainage area is limited. The results lend credence to the positive field monitoring results obtained to-date for the Stormceptor, and to the concept of small storm hydrology being the predominant parameter for urban stormwater quality design.

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NPDES Phase II Cost Estimates

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Introduction

The United States Environmental Protection Agency (EPA) has published final rules expanding the existing stormwater NPDES permitting program to smaller cities and other urban areas throughout the United States. Due both to external pressures and directives from the current and past administrations, EPA is conscious of attempting to make the current stormwater NPDES program "cost-effective." For example:

> "EPA believes this rule will cost significantly less than the existing 1995 rule that is currently in place, and will result in significant monetized financial, recreational and health benefits, as well as benefits that EPA has been unable to monetize, including reduced scouring and erosion of streambeds, improved aesthetic quality of waters, reduced eutrophication of aquatic systems, benefit to wildlife and endangered and threatened species, tourism benefits, biodiversity benefits and reduced siting costs of reservoirs." [1]

> ". . . the Agency recognizes the continuing imperative to assure that environmental regulations accomplish statutory objectives in the least burdensome and most cost-effective fashion. As explained further in this preamble, the form and substance of NPDES permits to address the sources designated in today's proposal would provide greater flexibility for the newly covered sources than the existing "standard" NPDES permit."[2]

While the "benefit" side of the proposed regulations exists in the realm of gross estimates, the "cost" side is also filled with unknowns. What will the mandated and negotiated stormwater program cost a local community? Are there ways to reduce costs? What should a local community be doing now to prepare for this regulatory program? This paper seeks to address these related questions.

The final regulations were published on December 8, 1999 and the changes from the draft regulations are only minor[3]. But it is still not possible to say what the regulations will cost everyone in toto. This is so because:

- there is great flexibility inherent in the regulations to create a stormwater quality program tailored to meet an individual community's needs and situation;
- each permit writer has preferences and "hot buttons" that will color what any particular program will look like; and
- each community setting is different in terms of climate, topography, pollutants of concern, and current condition of local waters.

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[1] Federal Register, January 9, 1998 p. 1536
[2] ibid. p. 1550
[3] Federal Register, December 8, 1999 pp. 68722-68851

Basic Approach to Permitting

Under proposed § 123.35(g), an NPDES permitting authority issues a general permit to authorize stormwater discharges from regulated small municipal separate storm sewer systems. The NPDES permitting authority will also provide a menu of regionally appropriate and field-tested Best Management Practices (BMPs) that the permitting authority determines to be "cost-effective." The regulated small municipal separate storm sewersystems could choose to select from this menu or select other BMPs that they feel are appropriate.

Under Phase II each regulated community will need to develop a set of BMPs under each of six specific program minimums. These BMPs can be any combination of programs, structures and other controls that, in the agreed opinion of the permit writer and the regulated community, meet the standard of reducing pollution discharge to waters of the state to the Maximum Extent Practicable (MEP). In this process, permittees and permit writers would evaluate the proposed stormwater management controls to determine whether reduction of pollutants to the MEP could be achieved with the identified BMPs. EPA envisions that this evaluative process would consider such factors as condition of receiving waters, specific local concerns, and other aspects included in a comprehensive watershed plan.

Under the proposed approach, implementation of BMPs consistent with stormwater management program requirements at § 122.34 and permit provisions at § 122.33 would constitute compliance with the standard of "reducing pollutants to the maximum extent practicable." That is, "if you do what you say you will do, you are by definition in compliance." It is important to note that states implementing their own NPDES programs may develop more stringent requirements than those proposed in the Federal Register. In fact, we anticipate that many states will require more specific and rigorous requirements under special circumstances relating to the condition of the receiving water within, and downstream from, the community. For example, if a certain stream is required to have a Total Maximum Daily Load (TMDL) or similar study performed on it (for example, a watershed assessment for the purposes of wastewater treatment plan permitting or expansion), the NPDES stormwater Phase II permit conditions may reflect the allocation of pollutants to that community.

The steps for a community are: (1) review the conditions of the general permit, (2) develop and submit a Notice of Intent (NOI) to comply with the general NPDES permit through description of a BMP-based program under each of the six minimum controls or program areas (see below), (3) negotiate this proposed program with the permit writer, (4) receive approval of the submittal, and (5) begin implementation of the conditions and programs described in the NOI including record keeping and submittal of appropriate reports describing attainment of "measurable goals" for each BMP as described in the NOI.

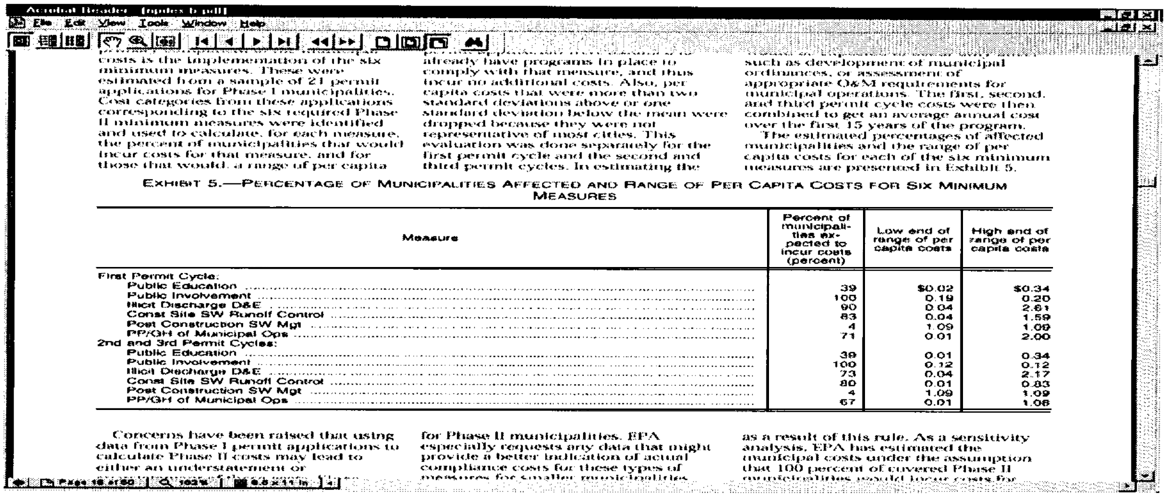
Current NPDES Phase II Program Cost Estimates

There is naturally much speculation on the actual program elements and costs for a particular stormwater program developed under Phase II. There have been several attempts at estimating Phase II program costs based on current costs of "similar" programs.

In the draft regulations, EPA had provided estimates of the probable cost implications of the NPDES Phase II Permit. These estimates were based on summary information from the permit applications from 21 Phase I cities. Very high and very low figures were thrown out by EPA in developing these estimates. Figure 1 shows the summary table developed by EPA.

The range depicted in Figure 1 is from $1.39 to $7.83 per person per year for the first permit five-year period, and $1.28 to $5.63 for other permit cycles. For a city of 50,000 that is a very wide range of $69,500 to $391,500 annually for the first permit cycle. This is clearly not helpful in attempting to estimate a specific community's costs.

There is question about the vagueness in the regulatory language, and the high degree of potential flexibility inherent in briefly described program elements. For example, for the first of the minimum controls the regulatory language states:



costs is the implementation of the six minimum measures. These were estimated from a sample of 21 permit applications for Phase I municipalities. Cost categories from these applications corresponding to the six required Phase II minimum measures were identified and used to calculate, for each measure, the percent of municipalities that would incur costs for that measure, and for those that would, a range of per capita

already have programs in place to comply with that measure, and thus incur no additional costs. Also, per capita costs that were more than two standard deviations above or one standard deviation below the mean were dropped because they were not representative of most cities. This evaluation was done separately for the first permit cycle and the second and third permit cycles. In estimating the

such as development of municipal ordinances, or assessment of appropriate O&M requirements for municipal operations. The first, second, and third permit cycle costs were then combined to get an average annual cost over the first 15 years of the program.

The estimated percentages of affected municipalities and the range of per capita costs for each of the six minimum measures are presented in Exhibit 5.

EXHIBIT 5.—PERCENTAGE OF MUNICIPALITIES AFFECTED AND RANGE OF PER CAPITA COSTS FOR SIX MINIMUM MEASURES

Measure	Percent of municipalities expected to incur costs (percent)	Low end of range of per capita costs	High end of range of per capita costs
First Permit Cycle:			
Public Education	39	$0.02	$0.34
Public Involvement	100	0.19	0.20
Illicit Discharge D&E	90	0.04	2.61
Const Site SW Runoff Control	83	0.04	1.59
Post Construction SW Mgt	4	1.09	1.09
PP/GH of Municipal Ops	71	0.01	2.00
2nd and 3rd Permit Cycles:			
Public Education	39	0.01	0.34
Public Involvement	100	0.12	0.12
Illicit Discharge D&E	73	0.04	2.17
Const Site SW Runoff Control	80	0.01	0.83
Post Construction SW Mgt	4	1.09	1.09
PP/GH of Municipal Ops	67	0.01	1.08

Concerns have been raised that using data from Phase I permit applications to calculate Phase II costs may lead to either an understatement or

for Phase II municipalities. EPA especially requests any data that might provide a better indication of actual compliance costs for these types of

as a result of this rule. As a sensitivity analysis, EPA has estimated the municipal costs under the assumption that 100 percent of covered Phase II

Figure 1. EPA Cost Estimates for Phase II NPDES Compliance.

1. Public education and outreach on storm water impacts[4].. You must implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of storm water discharges on water bodies and the steps that can be taken to reduce storm water pollution.

   (You may use stormwater educational materials provided by your State, Tribe, EPA, or, subject to the approval of the local government, environmental or other public interest or trade organizations. The materials or outreach programs should inform individuals and households about the steps they can take, such as ensuring proper septicsystem maintenance, limiting the use and runoff of garden chemicals, becoming involved in local stream restoration activities that are coordinated by youth service and conservation corps and other citizen groups, and participating in storm drain stenciling, to reduce storm water pollution. In addition, some of the materials or outreach programs should be directed toward targeted groups of commercial, industrial, and institutional entities likely to have significant storm water impacts. For example, information to restaurants on the impact of grease clogging storm drains and to garages on the impact of oil discharges. You are encouraged to tailor your outreach program to address the viewpoints and concerns of all communities, particularly minority and disadvantaged communities, as well as children.)

The "regulatory" wording in parentheses is not mandatory but suggested. There is wide room for interpretation of the intensity and detail necessary to accomplish this minimum control. The devil is always in the details, and there will always be great variability in what two different programs intend to do to accomplish the same general goals.

NAFSMA (1999a, 1999b) published a survey on potential Phase II program costs responded to by 121 cities and counties nationally. Ten communities responded with programs that had three or more suggested elements in the first minimum control: Public Education and Outreach. The annual per capita costs for these ten ranged from $0.04 to $1.17 – again a wide range.

Of those responding, only one community stated that it had program activity in each of the six minimum control measure areas and it spent $15.11 per capita annually, well above the EPA estimate (the city has a population of about 25,000). Of the 121 respondents only 26 had programs in at least three (most had only three) of the six mandatory minimum control areas, and these can be considered far from complete. Figure 2 shows the distribution of costs for these 26 programs. The vertical axis is the annual per capita cost for these elements. The median was $1.44 and the average was $4.07. The low value was $0.04 and the high was $26.00.

[4]Federal Register, January 9,1998, p. 1639.

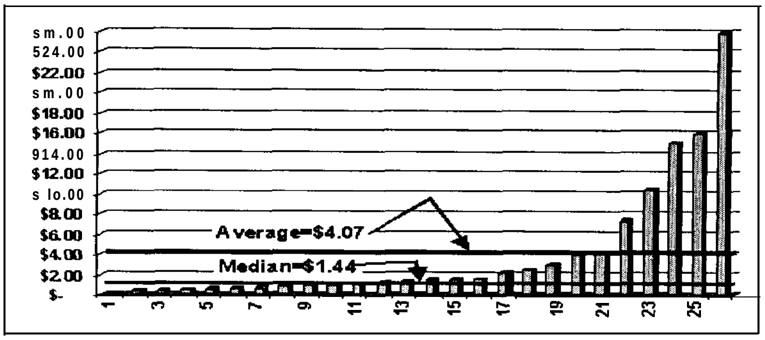


Figure 2. NAFSMA Study Program Costs.

We can speculate that if many of these communities had a fully developed Phase II program, the average costs could more than double, since each community would be adding both new program areas and upgrading their existing programs they had to make them comply with the details of the Phase II permit writers requirements.

In the final regulations, USEPA took a different approach to making estimates of the costs of compliance, using both the NAFSMA information and past experience with Phase I (EPA, 1999). EPA estimated annual costs for the municipal programs based on a fixed cost component and a variable cost component. The fixed cost component included costs for the municipal application, record keeping, and reporting activities. On average, EPA estimated annual costs of $1,525 per municipality. Variable costs include the costs associated with annual operations for the six minimum measures and are calculated at a rate of $8.93 annually per household (assuming 2.62 persons per household). The the cost estimating equation is:

Annual cost = $1,525 + population/2.62*$8.93

Finally, rule of thumb estimates based on the author's experience working in over 100 communities indicate that comprehensive stormwater programs that include advanced stormwater quality programs cost between $7.00 and $20.00 per capita per year – above the EPA estimates. The quality portion is normally between 20 and 30% of the total average program cost.

Estimating Costs from Anticipated Programs[5]

The methods used above do not provide details of the components of the stormwater programs resulting in the costs, and thus are not very helpful in assisting other communities in their thinking about the regulations. An effort was made to develop cost estimate ranges based on a direct interpretation of the stormwater regulations as applied to example communities at each end of the spectrum, in terms of size and intensity of water quality program. This has an advantage in that it deals directly with the stormwater regulatory requirements and illustrates specific program components so that we can control and define all details. The following sub-sections will develop two hypothetical permit applications for the six minimum controls.

The Two Permittees

Permittee one ("Smallville") is a community of 10,000 that is adjacent to a larger city that has obtained a Phase I permit or that can assist Smallville in many of its permit responsibilities. It is a small bedroom community interested in compliance with minimum disruption and cost. It does not really have an engineering or planning component of its city staff, but relies on a city administrator and hired consultants.

[5] Based on a presentation made by Andy Reese of Ogden Environmental at the APWA seminar, "Designing and Implementing an Effective Storm Water Management Program, Denver, 1998.

Permittee two ("Midtown") is a larger and more self-contained community with a population of 50,000 located within an urbanizing county whose total population makes it a designated "urbanized area." It is aggressively annexing growth areas, and has a thriving economy. It has a City Engineer/Public Works director, road maintenance staff, and other municipal capabilities and resources. It also has a growing stormwater quantity program and wishes to bring quality together with quantity in a comprehensive and integrated approach. It wants to take advantage of its GIS database and capability.

The Programs

We can assume that contained within, or subsequent to obtaining the general permit, the permit writer will publish a list of regionally appropriate BMPs to be used in permit applications. The general permit will have narrative effluent limitations which describe goals or narrative standards for each of the minimum controls. Each permittee must then develop basic program objectives and measurable standards (not included here) under the goals provided by USEPA for each of the six minimum controls. These measurable standards can be stated in terms of actions taken or results achieved. It is best to state them in terms of things that can be controlled and which do not have uncontrollable and unpredictable results.

It is also smart to schedule the programs (the schedule is not demonstrated here) in terms of phases, pilot programs, demonstration projects, trials, etc., with an evaluation process at some point in the permit. It should then be written into the NOI that this program will be modified, expanded, curtailed or even abandoned if it is not effective.

Smallville sought to obey only the letter of the law, but did not see many ways to proceed. It had no real stormwater program, no known water quality problems, and few current responsibilities. This community sought to take advantage of "big brother" next door in joint programs or education, and to adopt more regionally uniform development regulations enforced locally. Smallville sought to fund any program needs through budget changes and through economies gained by taking advantage of regional programs, free information, and expanding duties of existing staff.

Midtown sought to meet the program minimums in a more proactive way focusing on perceived needs within the community. They took advantage of the strength of existing local programs, a strong economy, a strong environmental awareness, and outside assistance where available in the form of copied resources and shared efforts. Midtown expanded its current program using EPA suggestions to build a more comprehensive and meaningful program in several key areas[6]. Because they did not have the ability to try to work regionally (the adjacent county had no resources for developing a stormwater program, but would cooperate as necessary) it needed to build the program alone and to work extra-territorially as appropriate. Midtown looked at each program to insure the existence of: adequate legal authority, competent technical approach, dedicated financial resources and appropriate administrative procedures and staffing.

Because program funding became an issue, Midtown sought to establish a stormwater user fee system (often called a stormwater utility) to provide stable, adequate and equitable funds. The costs and steps of the utility development are not included here.

Program Objectives

Table 1 develops the basic objectives of each of the programs in each of the six minimum areas. In real life these objectives would be developed through a series of discussions with staff and, perhaps, a citizen's group, and through early coordination with the permit writer.

Table 2, which is attached as an Appendix, gives basic cost-estimate information for the two programs. The costs are approximate and would vary depending on how all costs are accounted for, availability of staff, etc. The intent is to give <u>ballpark</u> estimates and not to quibble over details. In these estimates all personnel time is costed at $50/hr regardless of

[6] NAFSMA has taken an earlier version of the Midtown values, refined them, and developed a minimal and advanced program concept out of this information. That information can be obtained from NAFSMA by calling 202-218-4122.

the source of the labor (in-house or contracted). This corresponds to a fully burdened salary rate plus allocated overhead costs for a mid-level technical person.

Table 1. Basic Program Objectives

Smallville	Midtown
Public Education and Outreach on Storm Water Impacts	
1. Acquire and mail existing public domain informational brochures 2. Encourage and facilitate newspaper articles 3. Educate the few industrial and commercial stakeholders individually	1. Acquire and mail existing and specifically pertinent public domain informational brochures to the general public 2. Develop a stratified database of stakeholder groups and develop and execute targeted education programs 3. Develop and implement elementary school education programswith preexisting curriculum 4. Develop and advertise complaint hotline as a pollution hotline 5. Develop press information and briefings with the objective of having a quarterly news article 6. Develop and make available a slide show and speakers bureau
Public Involvement/Participation	
1. Develop and implement a citizens advisory group appointed by the mayor 2. Encourage citizen participation in the neighboring city's programs for used oil, household hazardous waste, adopt-a-stream, etc. through news articles in local neighborhood newspaper	1. Develop and implement a stratified and diverse citizens advisory group/task force 2. Develop a citizen monitoring and/or adopt-a-stream program -- may be partially federally funded 3. Develop a student storm drain stenciling program and student dry weather screening program (see illicit connections program) 4. Encourage the development of watershed groups for each major watershed within the jurisdiction (see BMP control)
Illicit Discharge Detection and Elimination	
1. Develop a stormwater major outfall map on USGS base map 2. Modify slightly and adopt a generic ordinance available from the state or other organization.	1. Develop a major stormwater system map and inventory on existing GIS topo. Base mapping 2. Cross-reference map with existing databases on NPDES permit holders (available from the state) and SARA Title Ill database to identify likely source of dry weather pollution 3. Develop an illicit connections and illegal dumping ordinance including hotspot program 4. Perform initial dry weather screening in several key parts of the city by student volunteers 5. Develop inspection and enforcement capabilities and resources, and develop a detection program using city staff and a database of potential specific locations 6. Advertise hotline and write news articles (see public education) 7. Advertise existing private used oil disposal sites (see public education) 8. Educate all public employees to recognize and report problems (see pollution prevention) 9. Develop automotive industry sponsorship of spill prevention, materials management, and inspection and education programs (see public education for part of this)
Construction Site Storm Water Runoff Control	
1. Modify the adjacent city's sediment and erosion control ordinance to meet the regulatory minimums 2. Modify plans review and inspection procedures to include program minimums 3. Train city secretary to collect phone complaints and take appropriate action on erosion complaints 4. Advertise the complaint line as part of the public education program.	1. Modify existing sediment and erosion control ordinance to include all the requirements of the regulations 2. Add a BMP section and clear design steps to the drainage manual 3. Conduct training and familiarization program for developers, contractors and engineers, as well as in-house training for inspectors 4. Insure hotline has a formal and defined ability to receive and properly process erosion complaints 5. Upgrade the erosion control inspection and enforcement program

Post-Construction Storm Water Management in New Development and Redevelopment	
1. Modify and adopt the adjacent city's stormwater ordinance regarding stormwater quantity and quality requirements to require similar controls and requirements. Add a maintenance requirement for BMPs and detention designs 2. Transform the inspection process to be able to inspect and enforce the new ordinance 3. Communicate the new requirements	1. Investigate and seek to institute zoning and policy changes to encourage density restrictions, transferable development rights, easier use of PUDs, limitation of impervious areas, conservation easements, mandatory floodplain dedication, etc. 2. Develop design guidance for the use of structural and non-structural BMPs 3. Develop and conduct an ongoing training program in the proper use of BMPs 4. Develop several BMP pilot projects to demonstrate and gain experience in BMP use 5. Overhaul and develop a comprehensive storm water ordinance for both water quantity and quality which includes mandatory use of BMPs and a maintenance requirement 6. Establish inspection program for private BMPs 7. Develop a monitoring program for local surface waters and to monitor their long term changes 8. Develop master plans for areas facing new development and establish and enact policy for regional BMP design and maintenance 9. Develop ways to improve extra-territorial planning and zoning input 10. Identify key environmentally sensitive areas and take steps to protect such areas through ordinance, overlay districts, etc. 11. Seek to establish local watershed organizations and neighborhood adopt-a-stream programs to assist in compliance and build public support
Pollution Prevention/Good Housekeeping for Municipal *Operations*	
1. Review all current municipal procedures and document ways to reduce pollution 2. Make changes and document 3. Obtain and distribute materials on ways to reduce pollution as available and appropriate.	1. Conduct an outside review of all applicable procedures and criteria and make recommendations for change, implement changes 2. Obtain available information and conduct sensitivity and familiarization training for all applicable city employees 3. Seek to control floatables partially through adopt-a-stream program (see public participation) 4. Review existing flood control projects to insure advantage is taken of pollution reduction opportunities in design and operation

Hours are given in most cases. Italicized numbers are one-time costs that are experienced some time in the first permit period, assumed to fill the year in which they initiate. For ongoing programs, the program initiates beginning in the next year. The annual costs are the anticipated costs thereafter. I have assumed that all programs initiate in year one for the total five-year cost estimate. Obviously if a program initiates in a later year there will be savings in annual costs not incurred until the program initiates. The five-year total is four times the annual cost plus the initial cost -- making a total of five years. Some programs are five-year programs only, ending after the first cycle.

A schedule of tasks and of manpower requirements is not developed in this paper. The costs are given as initial costs and as ongoing costs (clear from the context of the table). Because not all program elements will be developed and in-place for the whole permit term, there will be a ramp-up process. Also, most of the program elements will continue to change and evolve over time, and program costs will also change (up or down) in subsequent permit periods. Extraordinary volunteer efforts have not been assumed (e.g. writing news articles, manning a hotline, etc.).

It is important to realize that some per capita costs go down for large cities because they have a large fixed component. For example, it may cost the same to develop a one-page brochure whether the city has 20,000 or 200,000 people in it. Expenses are based on medium levels of effort wherever appropriate. Detailed expenses (e.g. long distance phone costs) have not been estimated.

Measurable goals have also not been provided in this handout. But for each BMP measure or program it will be necessary to develop some measurable standard by which to judge success. The standard may be based on internal activities where it cannot easily be based on external results. For example, sending out brochures three times per year can be measured. But, the effectiveness of those brochures can only be measured through phone surveys of public knowledge before and after the brochure was sent, or based on statistics on increased public participation in whatever program the brochure was about. Neither measure is easy and reliable. And, should a certain percent "effectiveness increase" be stated as the measurable goal, if it is not achieved the city would, technically, be out of compliance. Better to make the goal controllable, especially in the first permit cycles when little is known on the effectiveness of certain (especially non-structural) BMP measures.

In no case have the costs of structural BMPs been estimated or included. Cost estimates are available in several references including the Center for Watershed Protection (1997) and Northern Virginia Planning District Commission (1994). The economic benefits of structural BMPs are discussed in EPA (1995).

Monitoring costs are developed for Midtown based on both receiving stream monitoring and some pilot BMP program monitoring; they are non-existent for Smallville. EPA estimates that about 50% of permittees may incur monitoring costs in subsequent permit cycles. It is also assumed that there are no TMDL or other types of watershed assessment actions going on in the watershed which may radically modify the permit conditions, and that there are no regional or state-wide programs which could simply be adopted by reference for portions of the NPDES minimum requirements.

Summary Results

The summary results of the analysis are presented in Table 3, in terms of cost per capita, for each of the programs in a manner comparable to the EPA estimates.

The range of results is similar to that experienced by EPA in making its original estimates of the cost of the Phase II program. The details of this program development can assist a local community in fashioning its own stormwater program in response to the regulations.

Table 3. Summary Results

	Annual Per-Capita Cost	
Minimum Control	Small	Midtown
First **5-year** Permit Period		
1 - Public Ed.	0.39	1.24
2 - Public Inv.	0.21	0.62
3 - Illicit Connections	0.24	1.77
4 - Construction	0.20	0.96
5 - Post Const.	0.14	5.78
6 - Housekeeping	0.15	0.59
Totals	1.33	10.96
Subsequent **5-year** Permit Periods		
1 - Public Ed.	0.36	1.40
2 - Public Inv.	0.24	0.51
3 - Illicit Connections	0.10	1.16
4 - Construction	0.18	1.10
5 - Post Const	0.13	1.26
6 - Housekeeoina	0.10	0.20
Totals		**5.63**

The Phase II Action Plan

Given the great range in costs for the Phase II program it makes sense to get a jump start on planning for it. Many of the requirements or potential inter-local arrangements that could be developed take time to implement, more time than is available if the community waits until the general permit has been finalized and the NOI is due. There are steps that a local government should take now to prepare itself for the regulations and to position itself to meet compliance in the most cost-effective manner. These steps can be performed as part of a Phase II action plan:

1. Assess your status

Ask yourself if you are "in," "potentially in," or "out." Find out who else is in your category.

2. Get to know the permit writers

Find out what the permit writers are thinking about the permits, what the general permit will look like, when you will know more, how they will evaluate those potentially in, what other actions are going on in the state that may impact the permit, etc. Find out their ideas about what is important in the permit, what their special interests are, do they strongly support the permit, etc. Plan to establish an ongoing dialog.

3. Assess your surface waters

Find out if there are any ongoing actions which might designate surface waters in your jurisdiction as not meeting water quality standards. See if there are any planned watershed assessments or TMDL requirements coming in the future.

4. Assess your own program

How much of your own stormwater program looks like the regulations, even with some minor modifications. Can you get a jump on the requirements through transformation of your current programs?

5. Check out your neighbors

Are there some other programs nearby that might result in savings to you? Can you simply be covered under another program? Can parts of the requirements be waived because they are already being done by someone else? Can you plan to be part of a regional permit? Can you split the permit requirements with an adjacent entity and perform them together at savings to both of you?

6. Get a team together

Once you have answered some of these questions, it is time to pull the action team together. This may include only your own staff, a multi-disciplinary staff within your own jurisdiction, or a multi-jurisdictional or regional team. Get together to brainstorm and come up with a proposal to the permit writer which has mutual benefits. Remember, permit writers are being encouraged to think regionally and on a watershed basis.

7. Develop an action plan

Once you have a team, it is time to have a plan. Begin to formulate what you will need to do to apply for the permit and to carry it out. What might your program minimums look like? Are there some things you can do now, over several years, that you cannot afford to do in any one year, or that will take too long to get going if you wait until the permit is upon you? Can you begin the program transformation process now? What about data collection and mapping? Are there other uses for any data you will collect which will create synergy?

8. Get started

Some things are best started early. But do not jump the gun by committing resources in areas that are not yet anticipated to be firm. Ask the permit writer for his or her opinion.

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Appendix

Table 2. Hypothetical Program Detail and Cost Summary

Smallville Program Element	cost	Midtown Program Element	cost
Public Education and Outreach on Stonnwater Impacts			
Acquisition of available mailers and information from private institutions and other governmental entities - 20 hrs	$1,000	Acquisition of available mailers and information from private institutions and other governmental entities - 40 hrs	$2000
Keep up with available literature - 20 hrs/yr	$1000/yr	Keep up with available literature - 50 hrs/yr	$2500/yr
Coordination with neighborhood or shoppers newspaper to run articles on pollution sources - 4 hrs	$200	Stratified mailing database development for key stakeholder groups - commercial, automotive, minority, etc. - 100 hrs	$5,000
Develop 2 articles per year - 24 hrs/yr	$1,200/yr	Maintenance of database - 1 hr/wk	$2,600/yr
Coordination with the few individual potential sources of pollution about the program and their needs - 10 hrs	$500	Obtaining or developing educational materials for the specific outreach and stakeholders' programs, printing - 30 hr	$4,000
		Updating materials - 100 hrs/yr. Mailing 5,00 brochures per year	$7,500/yr
Series of three mailings - stuffers in utility bill	$3,600	Developing outreach and educational programs - 200 hrs	$10,000
One mailing per year afterward	$1,050/yr	Executing programs - updating, mailing, training, presentations - 200 hrs/yr	$12,000/yr
Responding to information requests - 1/2 hr/wk	$1,300/yr	Develop elementary and middle school education programs - preexisting Material/curriculum - free materials - 100 hrs	$5,000
		Ongoing program maintenance - refresher training, 5 schools - 100 hrs/yr	$5,000/yr
		Advertising of hotline - radio spots developed in-house and on public And other radio service spots and Newspaper ad, 3 times per year - 140 hrs - donated spots	$12,000/yr
		Develop white paper and press package - initial, brief - 32 hrs	$1,600
		Develop quarterly press package/briefing - brief press - 24 hrs per + expenses	$5,000/yr
		Development of a short, scripted stormwater pollution slide show, Presentation and speakers bureau & initial presentation - 60 hrs	$3,000
		Give presentations - 48 hrs/yr + expenses	$2,600/yr
		General informational brochure development and mailing - once/year - 60 hrs/yr - 25,000 inserts @ 0.50 per	$15,500/yr

Continued

Table 2. Cont.

Smallville Program Element	cost	Midtown Program Element	cost
		Responding to information requests - 2 hrs/wk	$5,200/yr
Initial Cost	$5,350	Initial Cost	$30,600
Annual Cost	$4,550	Annual Cost	$69,900
Total Cost (first 5 years)	$23,500	Total Cost (first 5 years)	$310,200
Total Cost (ongoing 5 -year period)	$22,750	Total Cost (ongoing 5-year periods)	$349,500
Public Involvement/Participation			
Development and implementation of a citizen advisory committee appointed by the mayor - 2 initial meetings - 14 hrs	$700	Development and implementation of a citizen advisory committee appointed by the council - 5 initial meetings - 70 hrs + expenses	$3,700
Quarterly meetings - 32 hrs/yr	$1,600/yr	Bimonthly meetings - 60 hrs/yr	$3,000/yr
Advertisement of the larger city's stream cleanup program in local shopper newspapers - news articles, and coordination with them in all such programs - 16 hrs/yr	$800/yr	Initial coordination of monitoring program and/or adopt-a-stream - 60 hrs - equipment purchase	$40,000
		Ongoing coordination and equipment, database maintenance - 100 hrs/yr + expenses	$15,500/yr
		Student storm drain stenciling program development and implementation - 80 hrs	$6,500
		Annual cost	$3,000
NOTE: italics are initial cost - for first year only		Watershed group encouragement - presentations, advertising - 50 hrs + expenses	$2,800
		Ongoing coordination, education - 4 groups - 20 hrs. per	$4,000/yr
Initial Cost	$700	Initial Cost	$53,000
Annual Cost	$2,400	Annual Cost	$25,500
Total Cost (first 5 years)	$10,300	Total Cost (first 5 years)	$155,000
Total Cost (ongoing 5 -year period)	$12,000	Total Cost (ongoing 5-year periods)	$127,500
Illicit Discharge Detection and Elimination			
Collect and plot field information on system locations and sizes - 5 hrs - contract	$7,000	Develop system map, perform inventory of major structures - 60 hrs + contract	*$150,000*
		Update map - 60 hrs	$3,000/yr
Adopt ordinance - 20 hrs	$1,000	Database development and GIS programming and mapping - 200 hrs + expenses of $3k	$13,000
Enforcement of ordinance - 20 hrs/yr	$1,000/yr	Database maintenance - 100 hrs	$5,000/yr

Continued

Table 2. Cont

Smallville Program Element	cost	Midtown Program Element	cost
		Ordinance development with public participation - contract	$20,000
		Initial dry-weather screen in parts of city - student volunteers - 240 hrs	*$12,000*
		One staff member 1 day/week for inspection and enforcement of Illicit connection program - + expenses	**$28,000/yr**
		Development of automotive or other specialty programs - 100 hrs + 1k exp.	$6,000
		Annual implementation of inspection and education - 1 day/wk	**$22,000/yr**
Initial Cost	$8000	Initial Cost	*$201,000*
Annual Cost	$1,000	Annual Cost	$58,000
Total Cost (first 5 years)	$12,000	Total Cost (first 5 years) $433,000	
Total Cost (ongoing 5 -year period)	$5,000	Total Cost (ongoing 5-year periods)	$290,000
Construction Site Stormwater Runoff Control			
Modify and pass new erosion control ordinance - 40 hrs	$2,000	Modify existing ordinance - public participation - 60 hrs	$3,000
Enforcement ordinance in inspection process - 50 hrs/yr	**$2,500/yr**		
Modify development procedures - 4 hrs	$200	Add BMP section to design manual - 140 hrs + printing cost	*$12,000*
Train secretary to handle calls - 8 hrs	$800	Conduct training sessions for staff and local development related persons - 80 hrs	$4,000
Handle erosion calls - 10 hrs/yr	**$500/yr**	Ongoing biannual training - 32 hrs/yr	**$1,600/yr**
		Develop hotline procedure for complaints reception - 10 hrs	$500
		Hotline @ 150 hrs/yr + expenses	**$8,500/yr**
		Upgrade erosion control program for more sites and more activities - one person two days/wk + expenses	**$45,000/yr**
Initial Cost	$2,600	Initial Cost	$19,500
Annual Cost	$3,000	Annual Cost	$55,100
Total Cost (first 5 years)	$14,600	Total Cost (first 5 years)	$239,900
Total Cost (ongoing 5 -year period)	$15,000	Total Cost (ongoing 5-year periods) $275,500	
Post-Construction Stormwater Management in New Development and Redevelopment			
Modify and get ordinance passed - 40 hrs	$2,000	Work on major policy changes in land use regulations - contract + 200 hours	*$100,000*
Enforce/explain new ordinance provisions - 1/2 hr/wk	**$1,300/yr**		
		Develop design guidance for BMPs - contract	$25,000
		Training program for BMP use - debvelopment - 24 hrs + contract	$3,000
		Annual training - 60 hrs/yr	**$3,000/yr**

Continued

Table 2. Cont.

Smallville Program Element	Smallville cost	Midtown Program Element	Midtown cost
		BMP Pilot projects - federal funding assistance - 5-year program - contract 5 yrs	$200,000
		Comprehensive stormwater ordinance with public participation - contract	$40,000
		BMP inspection and enforcement program - one person one day/wk + expenses	$25,800/yr
		Data collection program - SWAG	$30,000/yr
		Master planning for new areas for both quality and quantity - 2 mile Planning zone around -c5-year program -40 mi^2	$800,00 5 yrs
		Costs of administration of regional BMP program - SWAG	$4,000/yr
		Sensitive area identification program, ordinances and policy enactment- 5-year program - 100 hrs incl. Mapping 5 yrs	$25,000
Initial Cost Annual Cost Total Cost (first 5 years) Total Cost (ongoing 5 -year period)	$2,000 $1,300 $7,200	Initial Cost Annual Cost Total Cost (first 5 years) Total Cost (ongoing 5-year periods) Master planning	$393,000 $62,800 $644,200 $314,000
Pollution Prevention/Good Housekeeping fo Municipal Operations			
Review of all current procedures - modification of procedures - 40 hrs	$2,000	Review and modification of all applicable procedures and criteria contract	$25,000
Obtain and distribute educational materials - 10 hrs	$500	Site inspections and corrections - 5-year program - $5k/yr	$25,000 5 yrs
Annual cost of changed procedures - SWAG	$1,000/yr	Training for city employees on new procedures - 40 hrs + 10 hrs @ 75 persons + expenses	$42,000
		Review flood control projects for retrofit opportunities - contract	*$15,000*
		Annual cost of changed procedures - SWAG	$10,000/yr
T *0* T A L Initial Cost Annual Cost Total Cost (first 5 years) Total Cost (ongoing 5 -year period)	$2,500 $1,000 $6,500 $5,000	Initial Cost (without master planning) Annual Cost Total Cost (first 5 years without master planning) Total Cost (ongoing 5-year periods) Master planning	$107,000 $10,000 $147,000 $50,000 $800,000
T 0 T A L Initial Cost Annual Cost Total Cost (first 5 years) Total Cost (ongoing 5 -year period)	$21,500 $13,250 $74,150 $66,250	Initial Cost (without master planning) Annual Cost Total Cost (first 5 years without master planning) Total Cost (ongoing 5-year periods) Master planning	$804,100 $281,300 $1,929,300 $1,406,500 $800,000

The Stormwater Utility Concept in the Next Decade (Forget the Millenium)

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Abstract

In the mid-l 970's, the first stormwater utilities were viewed as novel innovations in a few western states. Today, just 25 years later, more than four hundred cities, counties, and special districts throughout the United States have established such utilities. The pace is accelerating, and the stormwater utility concept has moved from a novelty to a well-accepted management and funding approach. What will we see in the next decade?

The stormwater utility has been adapted to fit diverse stormwater management problems and needs across the United States. Program content, priorities, institutional and organizational structures, and rate methodologies have been tailored to fit local needs and municipal authority and practices that vary widely. Courts in several states, and even federal courts, have been engaged in resolving key issues, including but not limited to the legality of utility service fees and the use of other funding mechanisms.

Major changes in the concept are still emerging today. Stormwater quality has become a concern equal to flood control in many communities. The National Pollutant Discharge Elimination System Phase II stormwater permits have spurred a new round of interest in the stormwater utility concept among smaller communities. This is creating a demand for basic utility concepts suitable for small cities and towns, which will need to be less costly and simpler to implement and maintain. Concurrently, more large cities, urban and urbanizing counties, regional service agencies such as metropolitan sewer districts, and consolidated governments are investigating the utility approach. They will require more complex institutional and funding solutions.

Stormwater management itself is also changing rapidly. Interest and involvement in stormwater management have broadened. As combined sewer overflow programs, total maximum daily load (TMDL) negotiations, stormwater quality mandates, coastal zone management measures, and safe drinking water supply issues converge, more wastewater and even water supply utilities are engaging in stormwater management. Regional resource management programs, watershed-based master planning, multi-purpose cooperative efforts involving urban forestry and riparian corridor protection, and use of state revolving loan funds for stormwater quality projects are becoming more common.

Local programs are quickly evolving as well. They have become more comprehensive in scope, more costly, and more demanding of technical and administrative skills while the pool of resources has grown relatively slowly. Local governments are accepting responsibility for more components of the stormwater drainage systems or, in some cases, being forced to take on such responsibilities. Open streams, historic remnants or agricultural ditches and levees, and detention facilities are being included among the system components actively improved, operated, and maintained by local stormwater management agencies, A preventive orientation that minimizes problems is replacing reactive measures. Technology, such as geographical information systems and hydrologic and hydraulic modeling, is more widely available and more productive in support of stormwater management, even in smaller communities. Public involvement in decisions, policies, and even the operation of systems is increasing.

This paper examines these and other emerging trends that characterize where stormwater utilities are heading in the next decade.

Pressures Moving us from Draining the Swamp to Stormwater Management

Historically, local drainage flooding, erosion, and water pollution due to stormwater runoff have not been high priorities for municipal governments. Unless homes, businesses, valuable agricultural land, or public properties have been devastated by flooding or other “drainage” problems, competing priorities have generally garnered more public concern and thus more support from elected officials. As a result, stormwater management operations, regulatory measures, and capital investment were historically ignored or, at best, received inadequate attention and erratic funding. Stormwater management has been a “stepchild” among municipal programs.

Symptoms of this past disregard are evident in many cities and counties.

- Improvements to stormwater systems in many communities have been limited to site-specific facilities installed by subdivision and commercial developers.
- Design practices have traditionally emphasized collecting and discharging runoff from each property as quickly as possible, without regard for downstream consequences.
- Public maintenance of stormwater systems has typically been reactive, and usually limited to road rights-of-way where uncontrolled stormwater might impact traffic safety, degrade the integrity of road surfaces, or threaten valuable adjacent properties.
- Maintenance of stormwater systems located outside of road corridors has commonly been left to private property owners, who are rarely capable of or willing to properly improve, clean, and repair such facilities.
- Municipal governments have usually improved and maintained individual structures or reaches instead of entire drainage systems, creating a patchwork of pieces having widely varying capacity and reliability.
- Failures of substandard components frequently impair the performance of otherwise adequate parts of the systems and damage properties near them.

As described by one municipal public works official, this stepchild is also the “sleeping giant” of unmet municipal infrastructure needs. Long-term stormwater remedial repair costs potentially exceed street and bridge repair needs in many older cities. Learning the high cost of correcting stormwater management deficiencies through master planning may have frightened as many local jurisdictions into inaction as it has spurred others. Perhaps the classic example is the stormwater master plan for Key West, Florida, which (in the early 1990’s) identified $78 million in capital needs for that four square mile island community of less than 30,000 people.

Several factors are now changing local governments’ traditional orientation to stormwater management.

- Citizens’ service expectations are higher than in the past. In many cities and counties the number of citizen complaints about stormwater problems exceeds those about potholes in roads.
- Crumbling inlets and silt clogged ditches along roadsides spawn complaints even though they are on public property.
- Individual citizens or neighborhood associations no longer tolerate minor problems like localized flooding and channel erosion in backyards.

Environmental awareness in general is greater than in the past, and much more attention is being focused on stormwater impacts on receiving water quality in recent years.

- Stormwater management is now recognized as being part of an effective water resource protection strategy.
- Local concerns about acute threats of water pollution from spills and surreptitious dumping of toxic materials into stormwater systems are becoming more common.
- Phase II of the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program is extending the program to smaller communities and those larger urban cities that escaped Phase I due to combined sewer service area exemptions.
- Programs proposed by local governments in NPDES Phase II permit applications will cost many thousands of dollars per year in cities, towns, and urban counties.

An encompassing, umbrella perspective of water resource management is emerging.

- Solutions to combined sewer overflow (CSO) problems will have to balance optimization of wastewater transport and treatment facilities against stormwater quantity and quality concerns.
- Several coastal states have instituted restrictive limitations on stormwater runoff to protect fragile estuaries and offshore waters from stormwater impacts.
- Drinking water supply watershed protection measures have imposed stormwater runoff regulations on developers independent of local stormwater management control practices.
- The point is becoming clear. Drinking water is water. Wastewater is water. Stormwater is water. Ground water is water. It is all WATER!

In the face of these pressures, the inadequacies of traditional stormwater management practices and funding are more widely recognized. More comprehensive and cohesive programs that address both stormwater quantity and quality are emerging. Clearly, however, the diversity of our communities and their problems and priorities means that no single solution is appropriate for every county, city, town, and village. Nor can a single funding method or stormwater utility rate structure fit every situation. Stormwater service fee methodologies can be designed to meet the specific needs of each community and provide equitable, adequate, and stable funding. The key is to tailor the funding to a clear program strategy.

"Stormwater Utility" can have Many Meanings

The fact that the simple term "stormwater utility" obscures the various meanings it may encompass, results in many misunderstandings. The term may imply a funding and accounting method, an organizational approach, a management concept, or a combination of all these. In reality a "utility" provides an umbrella under which the financial, organizational, and management approaches of each local stormwater program can be orchestrated to achieve practical and efficient solutions. Responsibilities may be consolidated and focused. Substantial new funding may be generated. New technology, different management concepts, and upgraded support systems may be adopted. A comprehensive, preventive program may be instituted.

Changes in the Approaching Decade

The spectrum of the stormwater utility concept will broaden more in the next 10 years than it has in the 25 years since the first utilities were established. The definition of "conventional" will change. Smaller towns and even villages will need to employ simpler variations of the concept. Larger cities, urban counties, consolidated governments, and coordinated regional approaches will demand more complex institutional, organizational, and funding solutions. The following are a few of the changes that may occur.

NPDES Phase II Will Impact the Stormwater Utility Concept

The findings of a survey of Phase II cities conducted by the National Association of Stormwater and Flood Management Agencies (NAFSMA) and published in July, 1999 indicate that 17% of all the respondent communities did not know how they would obtain funding to meet the stormwater regulations. Nearly half indicated they were not currently spending money on any of the stormwater program elements mandated by the regulations. Nearly three-quarters did not have a public information or education program as the regulations mandate. The 54% of respondents that currently fund programs or activities that fit the Phase II regulations on average spend upwards of $4,000 per square mile, or about $2.79 per capita. The implication seems clear that the NPDES Phase II program poses demands on local governments that may cause them to look to the stormwater utility concept to meet their stormwater quality program funding requirements.

The typical community that found the stormwater utility concept attractive in the past was a mid-size to larger city undergoing rapid development. Analyses of their stormwater management needs and programs typically revealed initial costs of service ranging from $25,000/sq. mile to $50,000/sq. mile annually. Costs per capita were typically $10 to $30 annually, with smaller cities trending toward the higher end of the range. In this context, the NAFSMA survey data is not alarming. It suggests that the Phase II program costs will likely be in the neighborhood of five (5) to fifteen (15) percent of the typical cost of stormwater management at the outset of utility-based programs.

Given its cost implications, NPDES Phase II makes the stormwater utility concept attractive to a broader variety of cities, counties, towns, and villages. Many communities that do not suffer flooding or other drainage problems will find the revenue potential and flexibility of a utility service fee attractive in the face of NPDES permit requirements. This will result in utility approaches that are outside the current spectrum of our experience. The needs in individual small communities may be less diverse than in large cities and urban counties, but the range will be cumulatively broader among the communities involved in NPDES Phase II than in those that have implemented utilities previously.

New institutional arrangements and relationships will have to be devised. The "utility" concept will take on new forms. Use of interlocal agreements among several local jurisdictions will increase, with responsibilities in some cases concentrated in one entity capable of providing the range of services required or, conversely, allocated among several participants.

The limits of existing authorizing legislation in some states will be tested. Many states will need to adopt new legislation and amendments, giving local governments greater flexibility in dealing with their water resource management responsibilities. Courts in the various states, and perhaps even federal courts, will be challenged to arrive at some sense of continuity among the institutional and financial solutions characterized as "stormwater utilities." Whether the court decisions will enable rather than hinder local governments' efforts to comply with NPDES mandates is a key question.

Organizationally and financially independent stormwater utilities have been common to date. In the next decade more stormwater utilities will be integrated with other water resource programs: organizationally, through formalized working relationships, or through financial arrangements. Other resource management agencies and programs, including but not limited to health departments and growth management authorities, will demand a seat at the stormwater table.

As NPDES permitting is applied to smaller urban areas of less than 100,000 people, more of the regional wastewater and water utilities already serving those communities will assume stormwater management responsibilities. In some cases their involvement will be limited to water quality aspects. In others they will address both quantity and quality. Funding of stormwater management costs will simply be assumed by some of these existing utility agencies without changes in their rate methodologies. Others will establish independent stormwater cost centers and rate components to track spending and allocate costs. Some will even modify existing wastewater and/or water rate methodologies to better reflect the impact of stormwater control on costs of service.

As more small cities and counties seek to establish utilities, stormwaterfunding strategies and rate methodologies will need to minimize implementation costs, yet be more flexible to accommodate stormwater quality management costs and unique local needs. The urge to use a "cookbook" solution will cause some to adopt approaches that are poorly suited to their circumstances. The desire for more precision in service fee rate algorithms will lead to methodologies that give an illusion of greater refinement without actually achieving it.

The mandated involvement of smaller jurisdictions and more rural communities in stormwater management will spawn "paper utilities" established solely to generate added revenue. Most of these will be initiated without the foundation of a solid program strategy. Accountability will become a key issue in some of these communities within a few years. Political challenges based on accountability issues will cause some of these storm water utilities to be melded into other local agencies'or programs or even dissolved entirely before they have geared up to address their program priorities.

Despite NPDES storm water permit mandates, locally perceived needs will still predominate in setting priorities. Flooding will remain a more important local issue than storm water quality. NPDES mandates will influence actual spending priorities only slightly. Few communities will need to institute a utility service fee just to support their NPDES Phase II programs, but many will justify it (at least partially) on that basis because it is easy to blame unfunded federal mandates for new local taxes, assessments, and service fees.

The technological resources and expertise required will change from the traditional engineering emphasis to a multi-disciplinary mix. More natural science and social science skills will be needed. Operational practices will change as new technology and information management systems enable innovative approaches and result in greater efficiency. Greater use will be made of outsourcing because of limited personnel resources and the high cost of specialized equipment.

The Stormwater Utility Concept will Impact NPDES Phase II

Local approaches to stormwater management will influence the content of Phase II permits and attainment of NPDES objectives. Stormwater utilities offer both financial capability and flexibility. Except in rare instances, stormwater utilities will not be established strictly to address stormwater quality and NPDES permit requirements. Rather, they will have a broader stormwater management perspective. For many communities this will mean that water quality management activities to comply with their NPDES permit will be tacked onto other stormwater efforts. NPDES Phase II permitting will, within a few years, adjust to accommodate this reality in terms of permit mandates, technical and scientific standards, and reporting requirements.

Related issues ranging from combined sewer overflow strategies to drinking water protection will be melded with Phase II permit requirements because they have to be. Local stormwater quality management cannot independently meet the entire range of regulatory expectations operating strictly by reference to NPDES Phase II. Conflicts and primacy battles will identify inconsistencies and gaps between the issues and programs, and will ultimately filter down to changes in NPDES Phase II program priorities and the permit requirements imposed on local governments. The unknown is whether this result in responsibility shifting toward bigger agencies with more resources and a broader perspective or toward local entities that have the ability to identify and activate locally acceptable solutions.

Watershed-based regulatory programs will overtake jurisdictional-based regulatory programs like NPDES Phase II. The utility approach will broaden to encompass watersheds through agreements among counties and cities simply because utility funding has the proven capacity to generate sufficient funding in politically acceptable ways. The transition has already begun in some areas. Where TMDLs affecting discharges of all sorts into receiving waters are an issue, they will supercede the six minimum practices identified for NPDES Phase II, making them essentially meaningless. Scientifically based, public health driven measures to protect drinking water supplies, estuaries, lakes, fisheries, and recreational beaches will overwhelm the programmatic approach represented by NPDES Phase II.

You May Need a Program to Identify All the Players

Stormwater utilities were first established because no one wanted responsibility for stormwater management. Those involved were concerned only about the impact of stormwater on their “real” jobs. The utility approach provided a way to focus responsibility and obtain dedicated, if not always adequate, funding for stormwater management. If there had been another option that was working, the stormwater utility concept probably would never have emerged.

A key issue in the next decade will be whether stormwater utilities will be major protagonists or bit players among all those now crowding onto the stage. More established and better-funded water and wastewater utilities now recognize that stormwater influences their operations directly and, in some cases, dramatically. For example, TMDL-based wastewater discharge limitations may severely curtail development in some areas. Will local wastewater utility administrators (and local elected officials) allow independent stormwater management utilities to address stormwater quality when economic vitality is at risk?

Other interests are becoming involved in stormwater management. Water supply utilities face the requirements of federal and state legislation regulating sources of supply and treatment. Coastal zone management has recognized that many priority uses of the shorelines and near-shore areas are dependent on good water quality. Growth management is an emerging concept, and concurrency of infrastructure improvements with development approvals highlights the issue of deficient stormwater systems in many communities. Protection of endangered and threatened species, urban forestry, and riparian corridor protection all have a relationship with stormwater management.

The Walls Will Come Tumbling Down (or at least they better)

The proliferation of federal, state, and local water resource (and related) regulations in recent years has created an environment in which dispersed responsibility for water in various forms and for various purposes is rapidly becoming unworkable. The institutional barriers that have been created over the past hundred years or so to focus attention, energy, and responsibility no longer fit the public needs. As watershed-scale studies, planning efforts, and the concept of TMDLs clearly illustrate, water resources are inextricably bound together regardless of their temporary form, use, and character.

The next decade will see accelerating consolidation of water resource management responsibilities at the local level of government. This is contrary to the control interests of some individuals and entities, and will not happen silently or easily. Will cities, counties, and special districts relinquish a little (or a lot) of their control over water resources through interlocal agreements? Will they accept a regional entity for water supply, wastewatertreatment, stormwater management, or even water quality? What will be the effect on stormwater utilities?

What are the organizational implications of the coming changes in storm water management? Realistically, local governments change slowly. Public Works and Street Departments have historically been the lead organizations of storm water programs, but they rarely have had much involvement in water quality issues. If storm water quality begins to influence local priorities, it is more likely that water and wastewater utilities will assume storn water management responsibilities from Public Works and Street Departments than the reverse. Public Works agencies will have to upgrade their engineering and scientific capability or risk losing their storm water management role to water and wastewater utilities that are typically well-established, well-funded, and well-understood by the public.

The Ability to Innovate Will Exceed the Need

Most of the early stormwater utilities programs were rather narrowly focused, and the funding mechanisms supporting them were relatively simple. In recent years, however, there has been a shift toward more sophisticated and complex approaches to all aspects of stormwater management--from master planning to rate methodology design. Much of the credit goes to the explosive growth in information processing capability associated with the computer revolution of the past 20 years. It is not clear, however, that much of the added capability to innovate is necessary to meet stormwater management needs. This is not to suggest that opportunities to improve should be ignored simply because they are based on increasing capability to do so. The following examples demonstrate how the ability to innovate in stormwater through technology can run amok, and suggest how it should be managed to the benefit of people and the environment.

There is no substitute for understanding what is really important. One Southeastern United States city invested over $1 million dollars assembling a highly detailed location inventory of its stormwater systems on a relatively sophisticated data processing platform. Unfortunately, the need for the inventory was not premised on a clear program strategy, nor was adequate funding available or established concurrently to support capital improvements or maintenance enhancements that could be facilitated by the inventory. The local elected officials finally tired of the seemingly mindless spending on the inventory and refused to discuss program improvements. Today, nearly 10 years later, the inventory has not been maintained and is out of date, and few improvements have been made in the stormwater management program.

What is technically possible does not always make common sense, and what makes sense is not always technically possible. A Northeastern city recognized that the stormwater component of its wastewater service fee rate methodology (one that was based on water meter size and internalized within its water/wastewater rates) was not reasonably allocating the cost of stormwater services and facilities across the community. Change to a more rational approach was desired, so a thorough assessment of the range of options was undertaken. A broadly representative advisory committee aided in the selection process. A relatively simple stormwater rate concept was selected that segregates stormwater funding from wastewater and water service. It will allocate a portion of the cost of stormwater service on the basis of gross area and a portion on the basis of impervious area. Once the impact of the change on certain rate payers was recognized, however, the advisory committee decided that phasing in the new rate over three years was a better idea than making the change in one step. While the technical support requirements of the phased approach are not especially demanding, the public information and education challenge is enormous. Not only must the new rate methodology explained to the public; it and the phase-in concept must be explained every year for three years.

Errors by a Few Will Make Life Miserable for Many

As the number of stormwater utilities grows, there is a natural tendency among municipal managers to assume that the process and results have become standardized, and the experiences of another community can simply be transferred. In an effort to save money, some cities and counties have established utilities without sufficient foundation and have even adopted service fee ordinances without the benefit of a cost of service analysis or a rate study. Such misjudgments have led to some monumental errors that have the potential to erode if not destroy the viability of the utility concept in a region, a state, or even nationally.

One city recently established a stormwater utility and adopted rates based on internal analyses that did not define a program, project the cost of service, or estimate the rate base available to generate revenue. As a result, the initial service fee billing was for nearly three times as much total revenue as the administration had indicated it hoped to raise for stormwater management. Furthermore, sufficient public information and education had not **been** conducted prior to the initial billing, so the public did not understand the purpose of the billing. A lawsuit was filed, and a same judgement on behalf of the plaintiff has resulted in the servie fees being rescinded and revenues returned with interest.

Expectations Will Advance Faster than Programs

One common experience of the cities and counties that have established stormwater utilities is that public expectations for the program have exceeded the utility's ability to perform. This means that creating accurate expectations before a utility is established must be a high priority. One cause for unfulfilled expectations is that stormwater utility revenue streams are usually insufficient to address all the accumulated problems in a relatively short time. Initial stormwater utility service fees have typically been less than $3 month for single-family residences.

Perhaps more significant, however, is the fact that most stormwater utilities inherit programs and systems that are not only deficient, but also do not offer an adequate foundation for a good, more comprehensive, program. Utilities often must invest one to three years creating the foundation for the program before real results begin to emerge in the form of capital improvements, remedial repairs, upgraded maintenance, and more effective regulations. Ratepayers tend to have little patience, however, when they are writing checks regularly to a stormwater utility.

In the context of NPDES Phase II permits, public expectations of improvements in water quality need to reflect the complexity of water quality issues and the limited ability of local government to quickly alter conditions in receiving waters through informational and regulatory programs. Attempting to sell a utility to a community as a response to federal water quality mandates has been unsuccessful in several communities. The public recognizes that stormwater quality, while important, is still a minor part of the total cost of stormwater management. Unless a comprehensive quantity and quality control program strategy is apparent, it is difficult to generate support for a stormwater utility.

Are Green Lots Worth More Than Brown Lots? An Economic Incentive for Erosion Control on Residential Developments[1]

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Abstract

Construction sites are major contributors to nonpoint source (NPS) pollution. However, a lack of personnel to enforce erosion control regulations and limited voluntary compliance means that few developers apply effective erosion control. New approaches are needed to increase erosion control on construction sites if this source of NPS pollution is to be significantly reduced. We have tested whether an economic advantage exists for developers who use vegetative cover for erosion control, independent of advantages gained in addressing environmental or regulatory concerns. Improving residential lot appearance from muddy brown to green grass may increase the appeal of the lot to buyers. A market survey shows that homebuyers and Realtors perceive vegetated lots to be worth more than unvegetated lots, and this increased value exceeds the cost of seeding. Thus, developers can now be encouraged to invest in vegetative cover because of the potentially high return on the investment.

Introduction

Sediment Pollution and Construction Sites

Nonpoint source (NPS) pollution, produced from diffuse sources such as runoff from agricultural land, construction sites, and urban surfaces, is now the leading cause of surface waterqualitydegradation in the United States (Novotny and Chesters, 1989; Federal Register, 1990). In developing areas, construction sites are a major source of NPS pollution because soil erosion rates are increased dramatically when land is exposed and disturbed by excavation and vehicular movement (Harbor et al., 1995; Goudie, 1994; Goldman et al., 1986, Fennessey and Jarrett, 1994). In fact, some of the greatest soil erosion rates ever reported are associated with construction activities (Crawford and Lenat, 1989); erosion rates on construction sites are typically 2-40,000 times greater than rates under preconstruction conditions (Wolman and Schick, 1967; Harbor, in press). Sediment contributed to streams by construction sites can exceed that previously

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deposited over many decades under pre-development land uses, radically altering stream geomorphology and ecology (e.g., Wolman and Schick, 1967). The larger-than-normal sediment deposition in waterways frequently exceeds the natural capacity of the receiving water system to assimilate and equilibrate to the sediment influx (Paterson et al., 1993), causing rapid channel changes and increased probability of flooding, erosion, and sedimentation problems (Goldman et al., 1986).

In addition to sediment, construction sites generate other pollutants such as pesticides, nitrogen, and phosphorus from fertilizers, petroleum products such as oil and gas from machinery, soil stabilizers, construction chemicals, and washings from concrete or bituminous mixing and flushing operations (Koehn and Rispoli, 1982; Lemly, 1982). In some cases these pollutants are in particulate form or are adsorbed by soil particles and are transported with the suspended sediment in runoff from construction sites (Paterson et al., 1993; Bhaduri et al., 1997).

Although construction sites generate a wide range of potential pollutants, sediment overshadows all the other construction site pollutants in total ecological and economic impact on receiving waters (Lemly, 1982). It was estimated that 15 million tons of sediment were released from urban construction sites to surface waters in or near heavily populated areas in 1975 (Lemly, 1982). The North Carolina Department of Natural Resources and Community Development has stated, that "sediment and its effects on stream environments" is the "most widespread water quality problem in North Carolina" (Crawford and Lenat, 1989). Because construction activities predominantly occur near existing population centers, the waters that are most seriously degraded are generally those that are most frequently used (Lemly, 1982).

Economic Consequences of Sedimentation

In addition to environmental impacts, enhanced delivery of sediment to off-site areas from construction activities has significant economic effects (Table 1). These economic impacts result from lakes and streams becoming turbid and filling with silt, destruction of commercial aquatic species, the need for additional treatment of turbid water for industrial use, filling of harbors and navigation channels, loss of storage capacity of reservoirs, damage to drainage ditches, increased frequency of flooding, loss of aesthetic value in the environment, and loss of game habitat (Lemly, 1982; Wolman and Schick, 1967; Koehn and Rispoli, 1982). The economic burden of mitigating these environmental impacts is almost always placed upon the taxpayer, rather than on the operator of the construction site that is producing high sediment yields (Harbor, in press). By not paying to prevent the off-site transport of sediment through the use of erosion control measures, the developer allows sediment from the construction site to reach waterways where the economic and environmental costs of any impacts are paid by downstream landowners and the community as a whole, and not the developer.

Overall, annual expenditures for in-stream and off-stream impacts due to sedimentation in the United States exceeds $11.6 billion (Table 1). In-stream effects include impacts while sediment is in a waterway (stream, river, lake, or reservoir). Off-stream effects can occur before or after sediment reaches a waterway, either in floodwater or in water withdrawn from waterways to be used for industries, municipalities, or agriculture (Clark, 1985; Clark et al., 1985; Paterson et al., 1993). Although agricultural areas are far more extensive than construction sites, the mass of sediment per unit volume of runoff from urban and construction areas is 5 to 20 times greater than that of runoff from agricultural lands (Fennessey and Jarrett, 1994). In addition, construction sites are usually located in developing or developed areas, where potential impacts on infrastructure and other water uses are more severe than in rural areas. Estimates of agriculture's contribution to off-site effects range from 1/3 to 2/3 of the total (Clark, 1985; Clark et al., 1985; Colacicco et al., 1989, Pimentel, et al. 1995). Thus, urban off-site environmental impacts are probably on the order of $3.9 to $7.8 billion per year (1/3 to 2/3 of the total off-site effects), and are often borne by off-site landowners and communities. One of the main goals of erosion and sediment control regulations is to avoid these costs. The problem, however, is that developers have to pay to reduce erosion yet do not see any immediate return on this investment. Because there is little economic incentive for developers to control erosion, regulatory and educational approaches have been developed to improve construction site erosion control, and requests to impose impact fees on developers have increased (Trotti, 1997).

Table 1. Off-site damage costs from soil erosion by water in the United States

Type of Damage	Cost (millions in 1997 dollars*)
In-stream damage	
Recreational (fishing, boating, swimming)	3,886.0
Water storage facilities (dredging, excavation, construction of sediment pools)	1,340.7
Navigation (accidents, dredging)	1,088.1
Other in-stream uses (commercial fisheries)	1,748.7
Subtotal in-stream	8,063.5
Off-stream effects	
Flood damages (sediment damage to urban and agricultural areas)	1,496.1
Water conveyance facilities (sediment removal of drainage ditches and irrigation canals)	388.6
Water treatment facilities	194.3
Other-off stream uses (municipal and industrial, steam electric power plants, irrigation)	1,554.4
Subtotal off-stream	3,633.4
Total water erosion costs	11,696.9+

(Data based on: Clark et al., 1985)
*Conversion using Consumer Price Index from 1980-1997.
+ Assuming that effects are the same today as in 1980.

Vegetation and erosion control

The significant ecological and economic impacts of sedimentation provide strong motivation for erosion control. Soil erosion involves the detachment of soil particles by raindrop impact, wind-blown particle impact, wetting and drying cycles, freezing and thawing, and runoff, and the transport of detached soil particles by rain splash, wind and runoff

(Ekwue, 1990; Goldman et al., 1986). Climate, topography, vegetative cover, and soil characteristics are the principal factors that control soil erosion potential. Climate and soil characteristics cannot be readily controlled on a site, and topography is constrained by pre-existing conditions and the grading plan, leaving surface cover as the most easily modified variable that controls oil erosion on a site. Increasing vegetative cover on barren areas such as construction sites is an excellent way to impede soil erosion and decrease sedimentation (Fig. 1).

"Vegetative cover is the most effective form of erosion control... a properly revegetated soil will be protected from erosion indefinitely without any need for human attention" (Goldman et al., 1986, p. 6.23). Vegetation (especially close to the ground surface) protects the surface from raindrop impact and reduces the velocity of water flowing over the surface by increasing surface roughness and disrupting overland flow (Clark et al., 1985; Rogers and Schumm, 1991; Satterlund, 1972). The reduction of water velocity flowing over the surface and the breaking up of soil by plant roots increases the amount of infiltration, thereby reducing the amount of surface water flow (Clark et al., 1985). Vegetation also depletes subsurface water between rainfall events, which reduces the amount of runoff during storm events. In fact, vegetative stabilization on construction sites has been shown to reduce soil loss by 80% (Harbor et al., 1995) to 99% as compared to bare soil (Koehn and Rispoli, 1982). The cost of reducing soil erosion using vegetative cover depends on the materials used, but typical temporary seeding on a one-third acre residential lot in the Midwestern US costs from $250 to $325.

Regulations requiring construction site erosion control

In the US, the biological and physical impacts of off-site sedimentation have prompted local, state, and federal regulations requiring erosion and sediment control for construction sites. The National Pollution Discharge Elimination System (NPDES) is a national program that issues, monitors and enforces permits for stormwater discharges associated

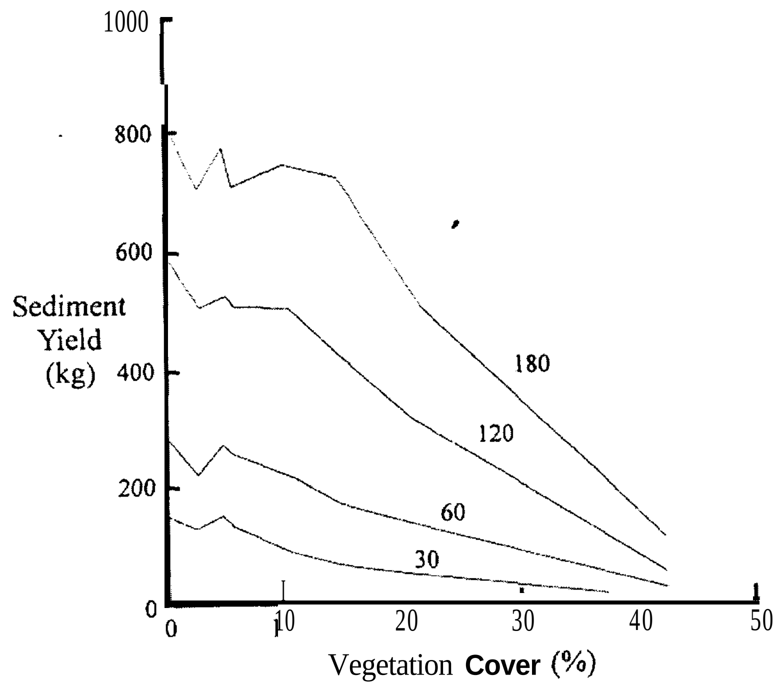

Figure 1. Sediment yields for different vegetative cover densities at 30, 60, 120, and 180 minutes of simulated rainfall on a 10% slope (Rogers and Schumm, 1991).

with industrial activity such as construction under the Clean Water Act (Federal Register, 1990). State and local regulators, under the NPDES program, require erosion and sediment control for construction sites with 5 acres or more of land disturbance (Federal Register, 1990). Because vegetative cover greatly reduces soil erosion, many federal and state regulations, such as Rule 5 in Indiana and the Model Regulations for Urban Soil Sediment Pollution Control in Ohio, encourage the use of surface cover as an important element of erosion control on construction sites.

In Indiana, for example, state regulations mandate that sediment should be contained on the construction site and not, for example, allowed to run onto public or private roadways. Rule 5 requires that if vegetative practices such as seeding and mulching are used, they must be implemented within seven days of the "last land-disturbing activity" at the site and that these actions are the responsibility of the person in charge of the construction activity, which usually is the developer (Indiana Department of Natural Resources, 1992). Similarly, in Ohio, Model Regulations for Urban Soil Sediment Pollution Control (1980) require that the responsible party for the development stabilize denuded areas with permanent ortemporary soil stabilization within seven days for any denuded area that has reached its final grade or is to remain dormant for more than 45 days. The permanent vegetation is not "considered established until ground cover is achieved which.. .provides adequate cover and is mature enough to control soil erosion satisfactorily and to survive adverse weatherconditions"(Ohio Department of Natural Resources, 1980).

Enforcement of erosion control regulations varies significantly among states. For example, in Indiana, the Indiana Department of Environmental Management (IDEM) controls permitting and enforcement, but local soil and water conservation districts (SWCD) review and evaluate erosion control plans. At typical staffing levels, SWCDs in developing areas find it very hard to keep up with the large number of developments they are responsible for. The local SWCDs inspect the construction sites to establish whetherthe developer is implementing the soil erosion control plan correctly and to observe whether the possibility of or the actual transport of sediment off-site exists. The SWCD will provide the developer with written recommendations describing which erosion control measures need to be improved, maintained, or installed. The developer then has two weeks to comply with the recommendations. If the developer is not found in compliance with the requirements after recommendations have been made, the SWCD reports the site to the Urban

Erosion Control Specialist from the Indiana Department of Natural Resources (IDNR), who has been receiving copies of all written warnings to the developer. The Urban Erosion Control Specialist will then visit the site and determine whether the site should be reported to the IDEM. Subsequently, the IDEM determines whether further action, such as levying a fine against the developer, is warranted. This process can lead to delays of many months between identification of a problem and regulatory enforcement.

In reality, it takes a great deal of coercion to get developers to promptly apply erosion control measures on their sites. Developers find applying erosion control measures inconvenient, costly, and time consuming, and are fully aware of the lack of regulatory personnel to enforce local, state, and federal mandated erosion control (Harbor et al., 1995). Therefore, developers often do not comply with the regulations and let their sites remain bare (Harbor, in press; Harbor et al., 1995). When inspected, sites are often either lacking erosion control measures or maintenance of existing control measures is long overdue. The effort (if any) on the developer's part to maintain or implement the erosion control measures is often inadequate and is done to appease the local SWCD, rather than with the goal of achieving 'best management' of the site. Aside from regulation, there is little incentive for a developer to use erosion and sediment control practices. In fact, a developer who uses erosion control may be at a cost disadvantage compared to other developers who do not, thereby making construction less profitable (Harbor, in press).

Origin of this study

In a study evaluating the use of rapid seeding and mulching to reduce NPS pollution from construction sites, one developer commented that he liked seeding because he thought that it made his developments more marketable (Harbor et al., 1995). The developer soon began to include extensive seeding on his other developments to achieve the same neat, green looking result. Even though the developer was interested in seeding because he thought it would give him a competitive edge over other developers, he was voluntarily using vegetative erosion control (Harbor et al., 1995; Harbor, in press). As similar anecdotal evidence accumulated, it seemed possible that a higher market value for a seeded site might provide an incentive for voluntary erosion control. If an economic advantage can be established, then it may be possible to persuade developers to use erosion control on the basis of a profit motive, where regulation and education have proved ineffective. If widespread voluntary application can be achieved by this means of increased profitability, it will make it easier to obtain compliance with erosion control programs and reduce the burden on regulators. Furthermore, and most importantly, the NPS pollution load from construction sites would be reduced.

Methodology

We hypothesize that green, grassed lots are more attractive to buyers and therefore may be valued more highly and sell faster than bare, dirt lots. There are several ways to test this hypothesis, with the most thorough being a detailed tracking of the sales prices and sales timing of a large number of randomly selected treated and untreated control lots on residential constructions sites throughout the US. In the absence of data to perform this type of highly detailed approach, we undertook a pilot study using photos of treated and untreated lots in a market survey questionnaire aimed at establishing whether lots with green vegetative cover are valued higher than barren ones by Realtors, developers, and homebuyers. In the work reported here, however, we do not evaluate whether green, grassed lots sell faster than bare, dirt lots.

Randomly selected lots in three residential housing developments in Ohio and Indiana were seeded and mulched. Photographs of these lots were taken prior to seeding and then when the grass was approximately one inch high (Fig. 2). Lots were photographed from three angles (front left, front center, and front right), and selected photos were used in a lot valuation survey. The market survey was designed as a broad tool to investigate a wide range of factors which homebuyers, Realtors, and developers find important when buying/selling a lot in a residential housing development. The survey included open- and closed-ended questions, and those surveyed were not told the actual purpose of the survey. The survey is reproduced in Herzog (1997). Included within the wide range of questions in the survey were specific questions on the importance of lot appearance, and a lot valuation question in which those surveyed were asked to place prices on lots shown in photographs. Those surveyed were told the lots were in the same neighborhood/subdivision, with the streets and curbs installed and had the samesewer/septic system, water system, and noise level. They were then

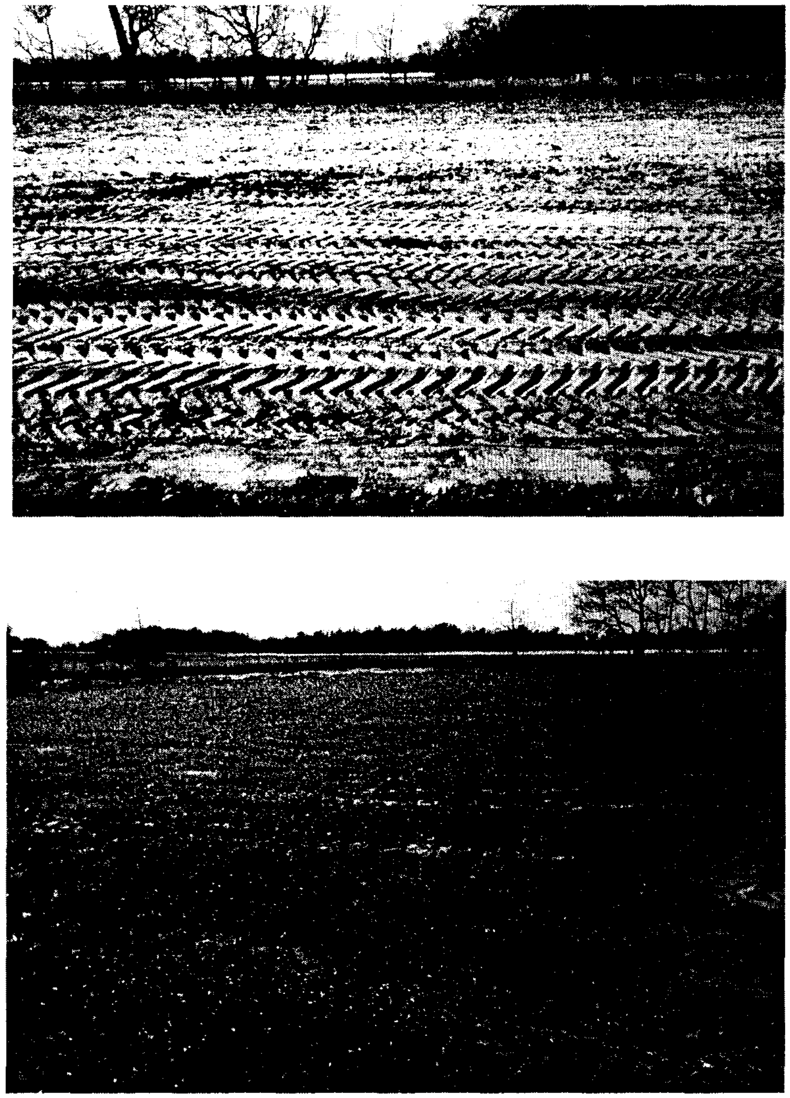

Figure 2. Examples of grassed and bare lot photographs used in the survey.

given 10 lot photos and asked to establish prices for each lot, having been told that the average lot value in the development was $20,000.

Most Realtors and developers were interviewed at their offices in St. Joseph County, Indiana and Geauga County, Ohio. Potential homebuyers were interviewed either at a neutral location or at their place of work, and included residents of St. Joseph County and West Lafayette, Indiana, as well as personnel at a chemical engineering facility in Buffalo, New York which was relocating to Philadelphia, Pennsylvania. The survey typically took 10-20 minutes depending on the responsiveness of the individual.

After completion of the surveys, comparative statistics were used on the lot valuation data to assess whether there was any significant difference between “brown” and “green” lot values for Realtors, developers, and homebuyers. Analysis of variance was initially used to be able to test for the existence of significant interaction between the fixed variables (respondent group and color), while taking into account variation that occurs in the random variables (eg., subjects). The assumptions needed to appropriately apply this method, such as normality of the error terms, were found to be satisfied (Montgomery, 1997).

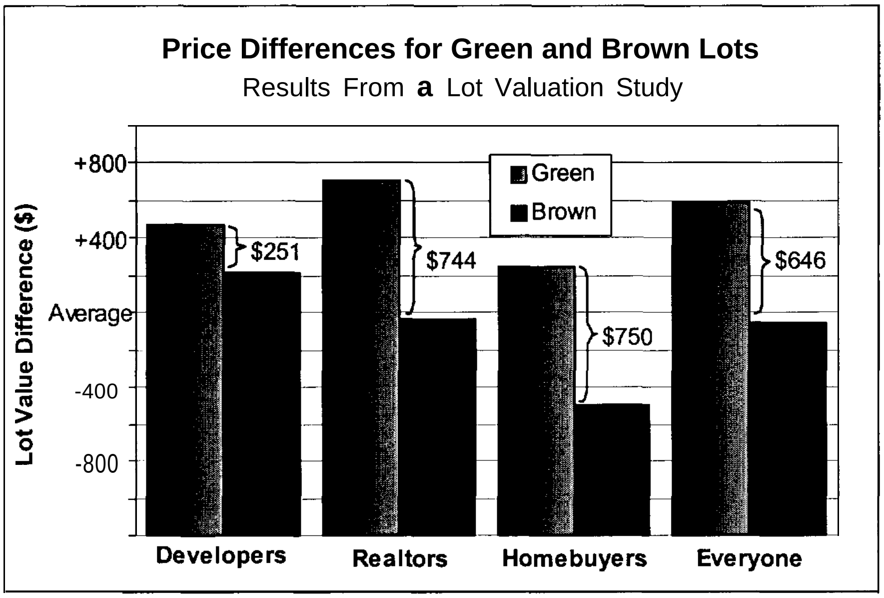

Figure 3. Differences in average prices for green and brown lots between survey groups.

Table 2. Effect of lot treatment on price for three different survey groups

Group	Green Lot Mean Price ($), sample size (n)	Brown Lot Mean Price ($), sample size (n)	Price Difference ($)	Test Statistic	Significance Level (p-value)
Realtors	20,711 (n=155)	19,967 (n=154)	744	t=4.0085	0.0001
Homebuyers	20,250 (n=36)	19,500 (n=36)	750	t= -1.7957	0.0788
Developers	20,469 (n=48)	20,218 (n=48)	251	t= -0.9200	0.3609

An important element of the economic analysis of lot greening is the actual cost involved in applying seed. This can vary widely depending on the method used to apply the seed, and the density of vegetation desired. In this work, we restrict the analysis to an amount and type of cover intended for erosion control, as opposed to grass species and density intended for final lawn cover. For this study we used independent contractors to apply seed, mulch, water and fertilizer by hydroseeding. Other common approaches include use of a hand seeder, and mulching with straw either by hand or using a blower. During dry seasons in some areas, watering may be necessary to produce successful germination and early growth. Thus there is a wide range of possible costs of lot greening. In this study we use the actual cost of hydroseeding for our study sites in Indiana and Ohio, $300 per lot, although we could have applied seed and mulch by hand for about $100 per lot. Readers may want to contact their local Soil and Water Conservation District to get estimates of typical costs for their areas.

Results

A total of 478 lot valuations (310 by Realtors, 96 by developers, and 72 by homebuyers) were made. However, during the survey process, it became apparent that two of the photographed lots were being ranked either highest or lowest based on their specific background (one with a fire hydrant and another with lush tree vegetation behind the lot giving an appearance of more privacy than the other lots). Lot valuations based on these two photos, one green lot and one brown were eliminated prior to the statistical analysis.

Initial statistical evaluation of the entire data set focused on determining if the data fit a model in which price was a function of the overall mean price, effects related to the group, the individual surveyed, the individual lot and the lot color plus interaction and random error terms. In this model we assume that the effect of the particular lot and the particular individual are random variables that are independently and normally distributed with a mean of zero, and also that the error terms are independently and identically distributed as normal random variables with mean of zero and variance σ^2. Analysis of variance followed by a normal probability plot of the residuals, and plotting of the residuals versus the predicted values, demonstrated that the error terms were normally distributed with constant variance (Montgomery, 1997). This analysis also demonstrated that there appeared to be significant differences in the variations of prices between groups, which complicates analysis of the data as a combined group. Thus it was necessary to analyze each group separately, using at test to evaluate the overall effect of color within each group.

Realtors

The Realtors surveyed gave an average value of $20,711 on the green grassed lots and $19,969 on the brown dirt lots. The distributions of lot values for green and brown lots were statistically significantly different at a 99.99% confidence level (Fig. 3, Table 2). As a simple difference between means, the perceived added value for green lots was $742 per lot.

Narrative questions on the survey revealed additional qualitative insight into Realtors' perceptions of lot value, and reasons for preferring green lots. One Realtor commented: "I don't like these mud lots." Others said the grass was more appealing and "easier on the eye," and that the lots look better because they are green. Other Realtors did not see the importance of seeding and believed that grass should not enter into the decision because it will be destroyed in the house building process. "Grass makes it look better but means nothing for what's coming."

Overall Realtors perceived that homebuyers would prefer the grassed lots ("I think people like grass,") and the green lots would sell first because the green grass will remind homebuyers of a yard and allow them to visualize what a house and yard would look like on the lot. One Realtor stated that the grass/ground cover was more appealing than dirt, and that homebuyers "wouldn't like the bare ones very much." Another noted that buyers would be more willing to walk a grassed lot in inclement weather lot because the grass would absorb the moisture and that buyer would not walk a dirt lot because it would become muddy and puddle. One Realtor stated: the green lots look "lush and fertile;" some people cannot visualize dirt lots as possibly being lush and fertile. This Realtor also brought up the concern that a buyer may ask about the drainage if the lot is wet, and if the dirt lot is dry, caked, and cracked, the buyer will wonder if anything can grow on it.

Homebuyers

The homebuyers surveyed placed an average value of $20,250 for the green lots and $19,500 for the brown lots. The distributions of lot values for green and brown lots were statistically significantly different at a 92% confidence level (Fig. 3, Table 2). As a simple difference between means, the perceived added value for green lots was $750 per lot. The added value of $750 (the greatest added value among the groups surveyed) is particularly significant because homebuyers are the ones who actually pay for the lots.

Homebuyers stated that grass gives a realistic impression of the future appearance of the lot and it is more appealing; and that the final product is more difficult to visualize on dirt lots. In general, the homebuyers acknowledged that the grass looks good and has more appeal, while understanding that the lots would be disturbed during construction. One homebuyer said that the green look was nicer but that it "wouldn't effect my decision to buy," because grass was not a "big deal." Even though comments such as these were made, on average homebuyers valued green lots $750 more than brown lots.

Developers

The developers surveyed placed an average value of $20,469 on the green lots and $20,219 on the brown lots. The distributions of lot values for green and brown lots were statistically significantly different at only a 64% confidence level (Fig. 3, Table 2). Typically this would be viewed as indicating no statistically significant difference. As a simple difference between means, the perceived value of the green lots was $250 greater than the brown lots. Clearly, the small difference between the green and brown lots data sets and the comparatively low significance level indicate that developers perceive little or no difference based on lot color.

During the survey, developers addressed the difference between the grass and dirt lots and stated that it should not be a factor in lot price. They pointed out that the green lots will become brown lots during construction and that the homebuyer will put in a yard anyway. Other developers saw that ground cover was more attractive ("I like the green") and perceived that homebuyers would like the grass. Also, some perceived that the green look made a development more marketable compared to other developments; one developer said he "greens up" his developments to make them look more attractive. Another stated that grass makes a lot look like it has topsoil, and if there are soil concerns, the grass demonstrates that vegetation can be grown and is holding soil. One developer remarked how ground cover may be important to homebuyers for more than just appearance. He stated that grass cover is more significant when there is rolling ground because if there is unseeded soil on an adjacent lot, the soil may erode onto the grassed property to the dismay of the homeowner.

The Economic Incentive

Although green lots may be priced higher than brown lots, this gross value is only significant if the price differential exceeds the cost of seeding. The difference in value between grassed and bare lots compared to the cost of seeding provides a measure of potential net economic benefit to the developer. In terms of a simple net return on investment, seeding a lot provides potentially excellent return. Homebuyers valued grassed lots $750 more than brown lots, and as it cost $300 to seed a lot in this study, the developer stands to profit by $450 per lot, which is a 150% return on the initial investment. The ability to more than double an initial investment should be an attractive and sensible advantage for the developer, if the perceived value difference actually translates into a sale price difference.

Present Limitations and Future Work

This pilot study is an initial step in developing information that can be used to persuade more developers to make widespread use of vegetative cover, and other forms of environmental protection. The results of this pilot study are most relevant in areas where climate conditions allow for relatively easy establishment of temporary vegetative cover, and are not applicable to arid or semi arid areas. In addition, budget restrictions limited the scale of the study. Although we collected 478 lot valuations from 62 respondents, a much larger study with respondents from many areas of the United States would overcome a potential criticism that the current study only represents conditions in a small portion of the Midwest. Developers are also more likely to notice results based on data collected within their region, especially if these are coupled with regional demonstration projects. Thus, the next logical step is to initiate a network of coordinated studies in regions experiencing rapid residential development. This would provide for analysis on a national as well as a regional level, and for comparisons between regions.

An additional limitation of the results presented here is that they consider only <u>perceived</u> increase in lot values. In actual sales transactions, buyers may not actually behave in the way they say they would on a survey. As a linked project, it would be desirable to track actual sales histories (timing and pricing) to provide a more complete picture of the actual economic impact of lot greening. Future research should include analysis of a large number of real-world transactions for which lot condition is known. This could be based on a large-scale, long-term study in which researchers intervene to change lot conditions on selected lots or developments. Alternatively, if some landowners are convinced by the results of this study, the experiment might occur naturally in the marketplace as the findings of our work are disseminated.

Further extension of the basic concept of examining the direct profitability of environmental protection is also possible. We were recently contacted by a consultant who had heard of the lot valuation study, and wanted a similar study performed on the increased value of lots next to ponds on developments. Although ponds are often built for stormwater control, and also aid in reduction of nonpoint source pollution, they can also have considerable aesthetic appeal. Thus, it would be potentially very useful to know what the return on investment on a pond is for a new residential development, both in terms of the increased price of lots adjacent to the pond, as well as the increase in average price in lots for the development as a whole because of the improved appearance of the development.

Conclusions

Showing that erosion control may be profitable provides a new way to reach developers who have failed to act on the logic that erosion control provides environmental protection and is required to comply with local, state or federal erosion control regulations. Evaluating the cost of environmental damage is not only very difficult, but also of little direct relevance to a developer who does not directly pay the cost of the damage. Land development is a business, with profit as a leading motive, so appealing to increased profitability is one potentially effective way to change behavior.

The pilot study described here indicates that vegetated lots are perceived to be more valuable and more desirable by Realtors and homebuyers. Realtors perceived that vegetated lots are worth more than barren lots (by $742). They also perceived that vegetated lots are worth more to homebuyers and that homebuyers would be willing to pay more for grassed lots. Homebuyers also perceived grassed lots to be more valuable and put the largest premium ($750) on the lots for all those surveyed. The added lot value is only significant if the price differential exceeds the cost of seeding ($300), which was the case for Realtors and homebuyers by $417 and $450, respectively. Developers valued the vegetated lots higher than non-vegetated lots by an average of $250, but the difference was not statistically significant. Even if it were significant, this price differential is less than the cost of seeding and indicates that developers perceive that seeding costs are greater than the benefits of vegetation. This perception of a net cost associated with greening a lot is perhaps why the market has largely failed to recognize this simple way to increase a property's value. Some developers did recognize the visual appeal of the grass and believed that a greened development would attract homebuyers more rapidly than a development that appears unkempt. However, thevaluation study indicates that developers have not aligned their perception of lot value with that of homebuyers.

An alternative way of interpreting the results is to consider the potential return on the investment in the vegetative cover. For a $300 investment the developer can receive a return of $750, i.e. a 150% return on investment. Such a rate of return is difficult to achieve in most conventional investments. Finally, price differential is not the only economic benefit of lot greening; if lots sell faster because of greening, profits will increase because of lower financing costs for capital invested in the development process. Further research is needed to clearly define the value of this potential economic impact associated with lot greening. However, at this stage it is possible to state that in addition to the environmental benefits, and regulatory requirements associated with using vegetation for erosion control, there may be significant marketing and thus economic returns associated with lot greening.

Education concerning the environmental benefits of erosion control, and enforcement of regulations have not produced widespread, effective use of vegetative cover for erosion control. Because developers generally do not perceive much incentive to vegetate their developments aside from complying with often-ineffective regulations, they typically do not. Typically a developer who is using erosion control practices believes s/he is at a cost disadvantage compared to other developers who are not, thereby making the developer following regulation believe s/he will be less profitable. Furthermore, the developer does not directly pay for the mitigation of the environmental impacts caused by the sediment leaving the site; it is the burden of the taxpayer instead. In this study, we have demonstrated that vegetating a development may be a profitable investment. Appealing to the profit motive will hopefully provide a way to generate widespread use of vegetative cover that also provides erosion prevention on construction sites.

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