LATIS: A Spatial Decision Support System to Assess Low Impact Site Development Strategies

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James L. Martin[3], Jeffrey A. Ballweber[4], Kim Collins[5], and Gaurav Savant[6]

Abstract

Significant advances have been made in the use of spatial and hydrologic models to quantify the impact of BMP/LID practices on water quality, but little research has focused on calculating the implementation costs associated with these BMP's when integrated with a decision support system (DSS). This research project had three phases. The first was a review and selection of a public domain water quality model. Hydrologic Simulation Program in FORTRAN (HSPF), an unsteady flow model, was selected as the hydrologic and water quality program. The second phase assessed the potential to link the model to a desktop Geographic Information System (GIS). The third phase focused on identifying BMP's that are often included in low impact development strategies, including implementation, operation, and maintenance cost data. This information was collected from several national sites and loaded into a database, which was later linked to the site's individual BMP's housed in the GIS. This allowed development costs for different combinations or configurations of BMP's to be calculated in real time.

Keywords: decision support systems, cost analysis, planning, runoff, urban hydrology, sustainability

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Introduction

Commercial, industrial, and residential development is increasingly challenged to minimize disruption of the natural hydrologic regime to comply with environmental regulations. In particular site plans are being evaluated based on their water quality and quantity impacts on a watershed scale. Site development plans that maintain the hydrologic regime and sustain water quality downstream are consistent with the approach described as smart growth or low impact development. Significant advances have been made in the use of spatial models, including geographical information systems (GIS) and sophisticated hydrologic models, to assess the impact of potential development. Similarly, experience with best management practices (BMP) provides good insight into how various management practices such as stormwater detention and vegetated areas contribute to improved water quality. The Tennessee Valley Authority (TVA), Environmental Protection Agency (EPA), Mississippi Department of Environmental Quality, and Mississippi State University encourage the use of low impact/smart growth strategies and want to make their application rapid and easy. The work described here is intended to advance that goal.

Objective

This project was performed to evaluate the potential of DSS tools that would allow users to balance watershed protection with smart growth/low impact site development strategies. Specifically, the Environmental Protection Agency (EPA) and Tennessee Valley Authority (TVA) needed a DSS that would:

- Predict time-varying runoff as a function of rainfall, site characteristics, and Best Management Practices (BMP) for development sites within the Southeastern U.S.
- Calculate BMP cost.
- Allow various scenarios to be compared for effectiveness and cost.
- Be GIS-based for input queries and for output displays.
- Run on a desktop computer.

- Be in the public domain to the maximum extent possible.
- Either posses the capability or be extensible to future capabilities to predict water quality variables

Approach

Assessment criteria based on the above objectives were used to select a hydrologic modeling approach from currently available public domain models suitable for assessing low impact site development. Available BMP effectiveness and cost information was compiled and selected information was incorporated in an easily retrievable spreadsheet form. A desktop GIS was selected for spatial data analysis and manipulation. Finally, the combined system was tested on an example – that of the American Eurocopter plant located at Golden Triangle Regional Airport in Lowndes County, Mississippi. The system was also tested on a 16.6 hectare commercial development in Hendersonville, Tennessee, and a 900 hectare potential industrial park in Tunica, Mississippi. Only the Eurocopter site application is discussed here. The methodology for the other two sites would be the same.

Hydrologic Model

The Hydrologic Simulation Program – Fortran (HSPF) model (Bicknell 2001; EPA 2004a) was selected as most likely to satisfy the project's requirements. HSPF computes the movement of water through a complete hydrologic cycle – rainfall, evapotranspiration, runoff, infiltration, and flow through the ground – and the associated transport of constituents with that flow.

The latest version of HSPF is Version 12, which is packaged with Version 3.1 of EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). BASINS is an integrated system of models and tools for performing water quality analyses of watersheds. It uses the commercial Arcview 3 GIS software package, which must be installed on the computer before BASINS can be installed. Some versions of HSPF can be run in standalone mode, but the EPA-supported version is run through a BASINS interface, WinHSPF (EPA 2004a).

WinHSPF runs under Microsoft Windows with a graphical user interface for input, model execution, and output displays. The interface is fairly straightforward, but is still in the early stages of deployment and does not support all the features of HSPF that are needed for evaluating site development.

BMP Database

A limited review of available data and guidance on BMP characteristics, removal efficiencies and costs was conducted in order to evaluate the applicability of available data and guidance. For the comparisons of effectiveness and costs within the selected modeling framework, three types of information were required: removal efficiencies, costs, and rates of infiltration. Contaminants of interest for this project include those defined in a 2004 draft in-stream monitoring protocol prepared by Tennessee Department of Environment and Conservation. The information considered relevant was then compiled in a Microsoft Excel spreadsheet for use.

Review and Assessment of Available Information

A plethora of data is available on BMPs, much of which is of limited use in design. There are a number of reports and databases available that compile results of BMP studies (e.g. the International Stormwater Best Management Practices Database (ISBMPD 2004); however, in many cases those reports and databases either have limited information on removal efficiencies of contaminants of interest or include such a wide range of removal efficiencies as to be of limited use. For example, in the ISMPMD, which compiled information from over 200 studies conducted during the past 15 years, nitrogen data are compiled and reported in six forms (nitrate+nitrite nitrogen, ammonia nitrogen, Kjeldhal Nitrogen, Organic Nitrogen Dissolved, Organic Nitrogen Particulate, and Total Nitrogen). The database contains only 13 records for Total Nitrogen removal efficiencies (for all BMP surveyed) that ranged from - 47 to + 62 percent. Similarly, five forms of phosphorus were tabulated with 22 records for Total Phosphorus removal efficiencies (for all BMP surveyed) that ranged from - 84 to + 80 percent. Such wide ranges from anecdotal evidence are not satisfactory for design.

After careful review, three sources of information were identified which contained sufficient and relevant information (for the purposes of this project) regarding the design and removal efficiencies of BMPs. These sources are:

- Stormwater Best Management Practices in an Ultra-Urban Setting (FWHA 2004)
- Post-Construction Storm Water Management in New Development & Redevelopment, BMP Fact Sheets (EPA 2004b)
- Georgia Stormwater Management Manual, Volume 2: Technical Handbook (Atlanta Regional Commission 2004)

Of the above, the Georgia Stormwater Manual was considered the most complete and applicable for the Southeastern United States. Information on removal efficiencies and infiltration rates (where available) was compiled from these sources. A variety of sources were surveyed which provided information regarding the costs associated with BMP implementation and are described by Wilkerson et al. (2005). The cost information sources provided a minimum, maximum, and average cost associated with construction of a particular BMP, as well as a cost formulation where applicable, and maintenance costs. Information from these sources was compiled in the BMP database.

BMP Database

Information on BMP removal efficiencies, costs, and rates of infiltration was compiled into a BMP analysis spreadsheet. The spreadsheet is subdivided into five worksheets, which are briefly described below.

Selection

The Selection worksheet is the main working sheet for BMP assessments. The selection worksheet is subdivided into three parts. Part A of the worksheet (see Figure 1) has a list box that allows the user to select a specific BMP for further analysis. Once the user selects the BMP, the information compiled on that BMP is presented. The information provided includes a range of removal efficiencies for the following water quality constituents: Total Suspended Solids, Total

Phosphorus, Total Nitrogen, Nitrate-Nitrogen, Metals, Bacteria, Oil and Grease, and TpH. Information on the construction and maintenance costs for the selected BMP is provided as low, high, and average values and as a unit cost where applicable.

Presently, Part A of the Selection worksheet is intended to allow users to rapidly screen the costs and effectiveness of specific BMP. For model implementation, specific values of BMP removal efficiencies and costs must be determined, which requires a more detailed analysis. To aid in this analysis, part B of the Selection worksheet (see Figure 2) includes links to embedded files for specific BMP from each of the three sources cited. Since there were inconsistencies in terminology among the sources, the original names for specific BMP were retained from each of these sources and grouped into like types. The user can select a specific BMP type and review guidance from each of these sources in order to aid in the final design and selection of a BMP, and in determination of removal efficiencies and costs.

The final part of the Selection worksheet, part C, is a link to an embedded file for the BOB In-Stream Monitoring Protocols. BOB provides guidance on what, when, where, and how to collect in-stream samples that may be used, for example, to evaluate or support the implementation of a BMP (Smith 2004).

Removal Data Table

The second worksheet is the Removal Data Table (Figure 3). The table is provided for more detailed information on specific BMP removal efficiencies and is the basis for the information included in Part A of the Selection Worksheet. Drop down menus for each column allow the user to rapidly sort among BMP or water quality constituents. References and links are provided for the source of the tabulated information.

Cost Data Table

The third worksheet is the Cost Data Table (Figure 4). This worksheet provides more detailed cost information and is the basis for the summary information in Part A of the Selection worksheet. References and links are provided for each source of cost information.

Maintenance Data Table

The fourth worksheet is the Maintenance Data Table (Figure 5) This worksheet provides more detailed maintenance information and is the basis for the summary information in Part A of the Selection worksheet. References and links are provided for each source of BMP maintenance information.

Infiltration Data Table

The fifth and final worksheet is the Infiltration Data Table (Figure 6). This worksheet provides more detailed information on available infiltration data and is the basis for the summary information in Part A of the Selection worksheet. The information is based on a limited survey and will be refined in subsequent phases of this project.

GIS Interface

Since the selected HSPF model is connected with ESRI Arcview as its underlying GIS engine, Arcview was selected as the GIS interface for integrating the BMP cost data and provide input to the hydrologic model. Arcview is not delivered with an extension that will calculate area required for the HSPF model analysis and for costing BMP scenarios. A search was made of the ESRI knowledge base (ESRI 2004) and a suitable extension identified. More than one extension may be found on the WEB site, but the one used as part of this project is simply called Area Tools. When the BMP theme is selected and the Area Tools extension is launched an additional column is added to the attribute table, which is in .DBF format, containing area values in various units. At this point the attribute table has an ID or name for each BMP plus an area calculation. The table is now ready for linking with the database containing BMP costs and characteristics.

Multiple approaches to linking the two tables were evaluated as part of this task. The first approach was to create all the area information inside Arcview and then export it to the external database/spreadsheet. This approach was unsatisfactory because of the static nature of the attribute data. A second approach tested involved linking the original Excel spreadsheet to Arcview. This also proved to be cumbersome, due to the difficulty in identifying columns and setting data types. The third approach tested involved importing the existing spreadsheet data into Microsoft Access. The primary advantages to the Access approach are:

- The data type setting for each column is easier to define
- Identification of each column heading is simpler
- The BMP cost data is relatively static, the BMP area is not
- Access has more analytical capabilities

Application to the Eurocopter Site

The BMP analysis spreadsheet, Arcview, and BASINS with the HSPF model were applied to the American Eurocopter site in Lowndes County, Mississippi, to test the approach and identify needed improvements. The Eurocopter site occupies 36 ha adjacent to the Golden Triangle Regional Airport in western Lowndes County, Mississippi. Figure 7 shows the site development plan.

Creating HSPF Input Data

Arcview was used to collect sub-watershed land use information to be used in the HSPF model. Post-construction drawings were used to generate area definitions from an original file in Autodesk AutoCAD structure provided by Neel-Schaffer Inc., the consulting engineering firm that designed the facility. These line drawings were imported into Arcview and converted to a shape file (see Figure 7). The land use areas were defined as pervious and impervious cover, and broken into sub-watersheds as required by HSPF. These values were compared to area values found in the original AutoCAD file to verify that spatial accuracy had not been lost during the translation. The sub-watershed information was then used to create the HSPF model site schematic.

The Phase I development consists of a manufacturing building, taxiway, and loading dock plus adjacent roads, parking areas, walkways, and lawns. Phase I developments were delineated into sub-catchment areas as shown in Figure 8 for calculating rainfall-runoff. The site grading plan was used to identify the runoff pathways and slopes of the site. The resulting drainage schematic is shown in Figure 9.

Creation of HSPF Model

Three site configurations were tested with HSPF using meteorological conditions for the period March 1992 through June 1995:

- Predevelopment
- As-built 1
- As-built with multiple BMP
- As-built with a single BMP in the outlet channel

Results

No field observations were available with which to validate the hydrologic model. Since this effort was intended to be a proof of concept, the absence of field data was worrisome, but not insurmountable. Using a range of infiltration and storage coefficients helps increase confidence in the results, but they should still not be used for design until corroborated by field data. Limited testing of scale effects (Collins et al, 2006) showed that sites on the order of the Eurocopter development could be successfully modeled using HSPF and coeffiicents used for watershed-scale applications, which are numerous.

Figures 10, 11, and 12 show the site total runoff rate for four tested configurations under a typical rainfall event on 3 May 1994 in which about 2.5 cm of rain fell in 6 hours as depicted in Figure 10. Figure 10 shows the high and low estimates for the as-built conditions along with pre-development conditions, with which they overlap.

Figure 11 shows the effect of multiple BMP compared with the as-built condition. The multiple BMPs were effective, reducing the peak discharge to a lower level (0.035 m^3/sec) than predevelopment conditions; however, they would be expensive. Based on cost information found in the BMP database, a combination of extended detention wetlands, pocket wetlands, and vegetative channels would have cost in excess of $500,000.

Figure 12 show results for a single checkdam. The peak discharge was significantly reduced, from the as-built high estimate of 0.071 m^3/sec to about 0.035 m^3/sec, the same as the multiple BMP solution and lower than the pre-development low estimate. The BMP database indicates that a wet basin costs \$17 to \$35 per m^3 to construct from scratch, which for the 850 m^3 size would be \$15,000 to \$30,000, less expensive than the multiple BMP; however, since the channel is already there, it would cost only \$5,000 to \$10,000 to build the specified checkdam with an earth core and riprap covering. This latter cost is well within the range of acceptable implementation costs.

Conclusions and Recommendations

As stated earlier, this study's objective was to evaluate the potential for a tool set incorporating a public domain hydrologic model and BMP assessment data linked to a desktop GIS. The basic objectives were met, but with qualifications. Summaries for each component are listed below.

BMP Database

The initial development of these tools has provided a framework that can be used, given available information, to aid in the evaluation of the removal efficiencies of selected BMP, and the associated cost of those BMPs. The database limitations are a result in part from the lack of detailed information on the removal efficiencies and costs of BMP. Limits also result from the lack of relationships between the design of BMP (for example sizing) and constituent removal efficiencies. Additional review, and perhaps research, is required in order to develop improved methods for relating BMP design to costs and removal efficiencies. Field scale studies coupled with high-resolution modeling of specific BMPs is recommended for consideration in future project phases as an aid developing and evaluating BMP removal efficiencies and design alternatives.

The present version of the BMP analysis spreadsheet is not directly linked with the GIS or hydrologic model. More direct linkages are recommended, and are planned for development under later phases of this work effort.

GIS Interface

ESRI Arcview was chosen for the GIS interface to be tested. This was due to two factors: ESRI's widespread acceptance and the requirement that the hydrologic model HSPF have access to Arcview, even though it not in the public domain. At some time in the near future ESRI will probably phase out Arcview as a standalone package, in favor of ArcGIS. This will result in a more costly implementation for individual users, but one with greater customization options, as well as an easier migration to the WEB, which may be the ultimate solution. The database model of ArcGIS is also more robust, providing greater ease of linkage with external databases. Another option that should be tested is to include CAD as well as GIS for the spatial interface. Substantially more engineering offices use CAD as a normal part of their daily operations than use GIS. This trend will probably change over the next decade as more public agencies require submission of public engineering project in GIS rather than CAD format. But for now CAD is the dominant desktop tool for collecting and analyzing spatial data in engineering offices. By incorporating CAD in the process it would be easier, and cheaper, for engineering firms to adopt the new technology.

Hydrologic Model

HSPF can be used to evaluate development site hydrology and management practices that preserve site hydrologic responses. Further, HSPF's modules for water quality and BMP's can be employed to evaluate water quality management measures. The process by which the Eurocopter site was modeled required several manual processing steps that made the process cumbersome and ill-suited for widespread adoption. Automating those steps in BASINS, WinHSPF, AutoCAD, and/or some new interface will improve the process. WinHSPF proved to be awkward because it does not support some HSPF features essential to this purpose. HSPF modules are not optimally formulated to reproduce best management and low impact development measures. Improvements to allow reach flows into land segments and detention structures on land segments will significantly improve the model's capability to assist with site development issues. Scalability, i.e., running the model on small sites using coefficients and equations known to work for watershed-scale applications, remains an issue despite limited testing which suggests that the process works for sites of the tested size.

Peer Review of the Model

A peer review of the model was held in Starkville, MS March 23, 2005. Twelve participants selected from a cross section of public, private, and non-profit organizations attended. The morning session included demonstrations and discussion of the model, followed by a working lunch and a facilitated session to review the work, to determine any issues with the project, and to identify the next steps to be taken. The overall assessment was positive. A series of prioritized improvements was generated, including making the product more user friendly, showing the cost benefit/advantages of the BMP’s better, and validating the accuracy of the model. A series of target markets were also identified, including engineers, developers, and public sector agencies such as DEQ.

Acknowledgments

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Donald C. Becker and Dennis S. Painter served as TVA liaisons and provided technical guidance.

Arcview is a registered trademark of Environmental Systems Research Institute (ESRI).

Windows, Excel, and Access are registered trademarks of Microsoft, Inc.

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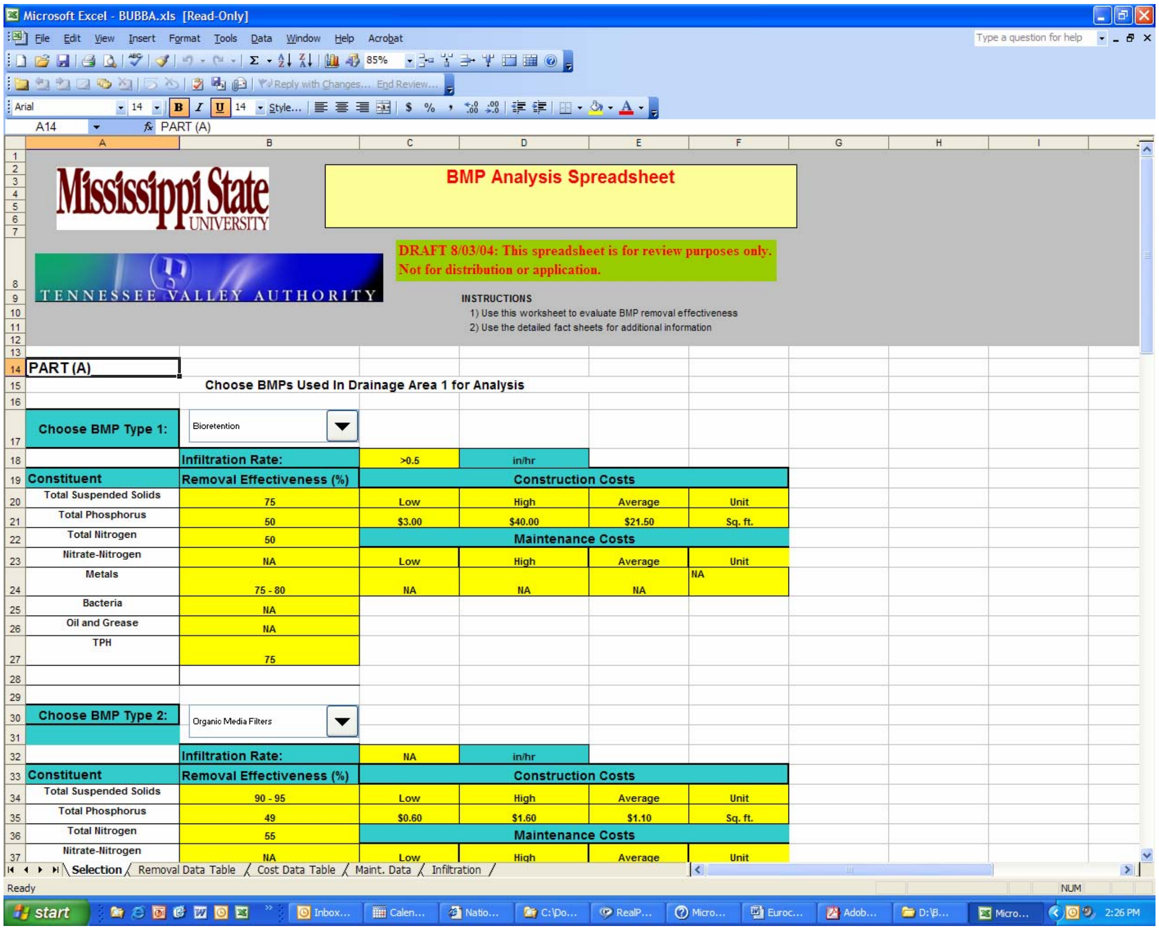
List of Figures



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Mississippi State UNIVERSITY

TENNESSEE VALLEY AUTHORITY

BMP Analysis Spreadsheet

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INSTRUCTIONS
1) Use this worksheet to evaluate BMP removal effectiveness
2) Use the detailed fact sheets for additional information

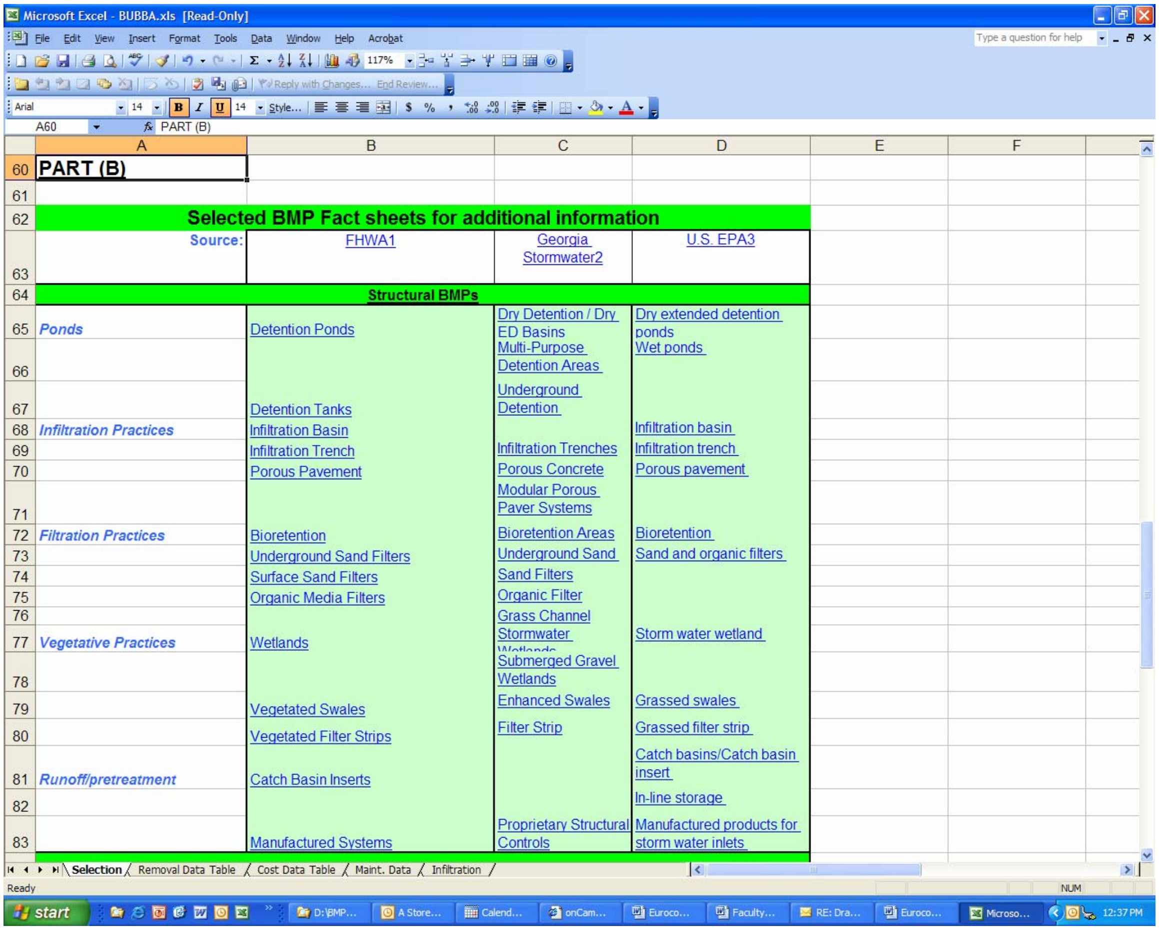
PART (A)

Choose BMPs Used In Drainage Area 1 for Analysis

Choose BMP Type 1:	Bioretention				
	Infiltration Rate:	>0.5	in/hr		
Constituent	Removal Effectiveness (%)	Construction Costs			
Total Suspended Solids	75	Low	High	Average	Unit
Total Phosphorus	50	$3.00	$40.00	$21.50	Sq. ft.
Total Nitrogen	50	Maintenance Costs			
Nitrate-Nitrogen	NA	Low	High	Average	Unit
Metals	75 - 80	NA	NA	NA	NA
Bacteria	NA				
Oil and Grease	NA				
TPH	75				
Choose BMP Type 2:	Organic Media Filters				
	Infiltration Rate:	NA	in/hr		
Constituent	Removal Effectiveness (%)	Construction Costs			
Total Suspended Solids	90 - 95	Low	High	Average	Unit
Total Phosphorus	49	$0.60	$1.60	$1.10	Sq. ft.
Total Nitrogen	55	Maintenance Costs			
Nitrate-Nitrogen	NA	Low	High	Average	Unit

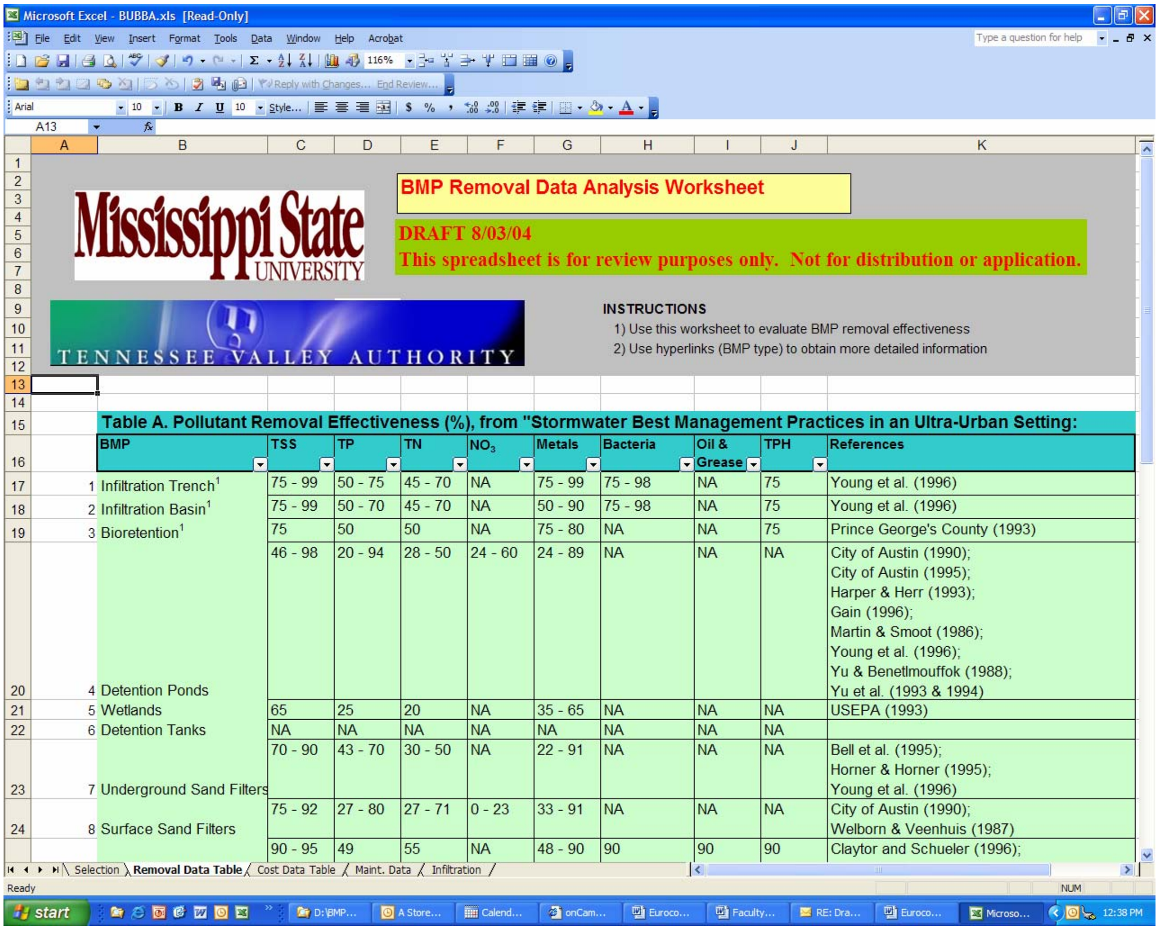
Selection / Removal Data Table / Cost Data Table / Maint. Data / Infiltration

Figure 1. Part A of the Selection worksheet



	A	B	C	D
60	**PART (B)**			
61				
62	**Selected BMP Fact sheets for additional information**			
63	Source:	FHWA1	Georgia Stormwater2	U.S. EPA3
64	**Structural BMPs**			
65	*Ponds*	Detention Ponds	Dry Detention / Dry ED Basins	Dry extended detention ponds
66			Multi-Purpose Detention Areas	Wet ponds
67		Detention Tanks	Underground Detention	
68	*Infiltration Practices*	Infiltration Basin		Infiltration basin
69		Infiltration Trench	Infiltration Trenches	Infiltration trench
70		Porous Pavement	Porous Concrete	Porous pavement
71			Modular Porous Paver Systems	
72	*Filtration Practices*	Bioretention	Bioretention Areas	Bioretention
73		Underground Sand Filters	Underground Sand	Sand and organic filters
74		Surface Sand Filters	Sand Filters	
75		Organic Media Filters	Organic Filter	
76			Grass Channel	
77	*Vegetative Practices*	Wetlands	Stormwater	Storm water wetland
78			Submerged Gravel Wetlands	
79		Vegetated Swales	Enhanced Swales	Grassed swales
80		Vegetated Filter Strips	Filter Strip	Grassed filter strip
81	*Runoff/pretreatment*	Catch Basin Inserts		Catch basins/Catch basin insert
82				In-line storage
83		Manufactured Systems	Proprietary Structural Controls	Manufactured products for storm water inlets

Figure 2. Part B of the Selection worksheet.



BMP Removal Data Analysis Worksheet

DRAFT 8/03/04

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INSTRUCTIONS

1) Use this worksheet to evaluate BMP removal effectiveness

2) Use hyperlinks (BMP type) to obtain more detailed information

Table A. Pollutant Removal Effectiveness (%), from "Stormwater Best Management Practices in an Ultra-Urban Setting:

	BMP	TSS	TP	TN	NO_3	Metals	Bacteria	Oil & Grease	TPH	References
1	Infiltration Trench[1]	75 - 99	50 - 75	45 - 70	NA	75 - 99	75 - 98	NA	75	Young et al. (1996)
2	Infiltration Basin[1]	75 - 99	50 - 70	45 - 70	NA	50 - 90	75 - 98	NA	75	Young et al. (1996)
3	Bioretention[1]	75	50	50	NA	75 - 80	NA	NA	75	Prince George's County (1993)
4	Detention Ponds	46 - 98	20 - 94	28 - 50	24 - 60	24 - 89	NA	NA	NA	City of Austin (1990); City of Austin (1995); Harper & Herr (1993); Gain (1996); Martin & Smoot (1986); Young et al. (1996); Yu & Benetlmouffok (1988); Yu et al. (1993 & 1994)
5	Wetlands	65	25	20	NA	35 - 65	NA	NA	NA	USEPA (1993)
6	Detention Tanks	NA	NA	NA	NA	NA	NA	NA	NA	
7	Underground Sand Filters	70 - 90	43 - 70	30 - 50	NA	22 - 91	NA	NA	NA	Bell et al. (1995); Horner & Horner (1995); Young et al. (1996)
8	Surface Sand Filters	75 - 92	27 - 80	27 - 71	0 - 23	33 - 91	NA	NA	NA	City of Austin (1990); Welborn & Veenhuis (1987)
		90 - 95	49	55	NA	48 - 90	90	90	90	Claytor and Schueler (1996);

Figure 3. Removal Data Table Worksheet.

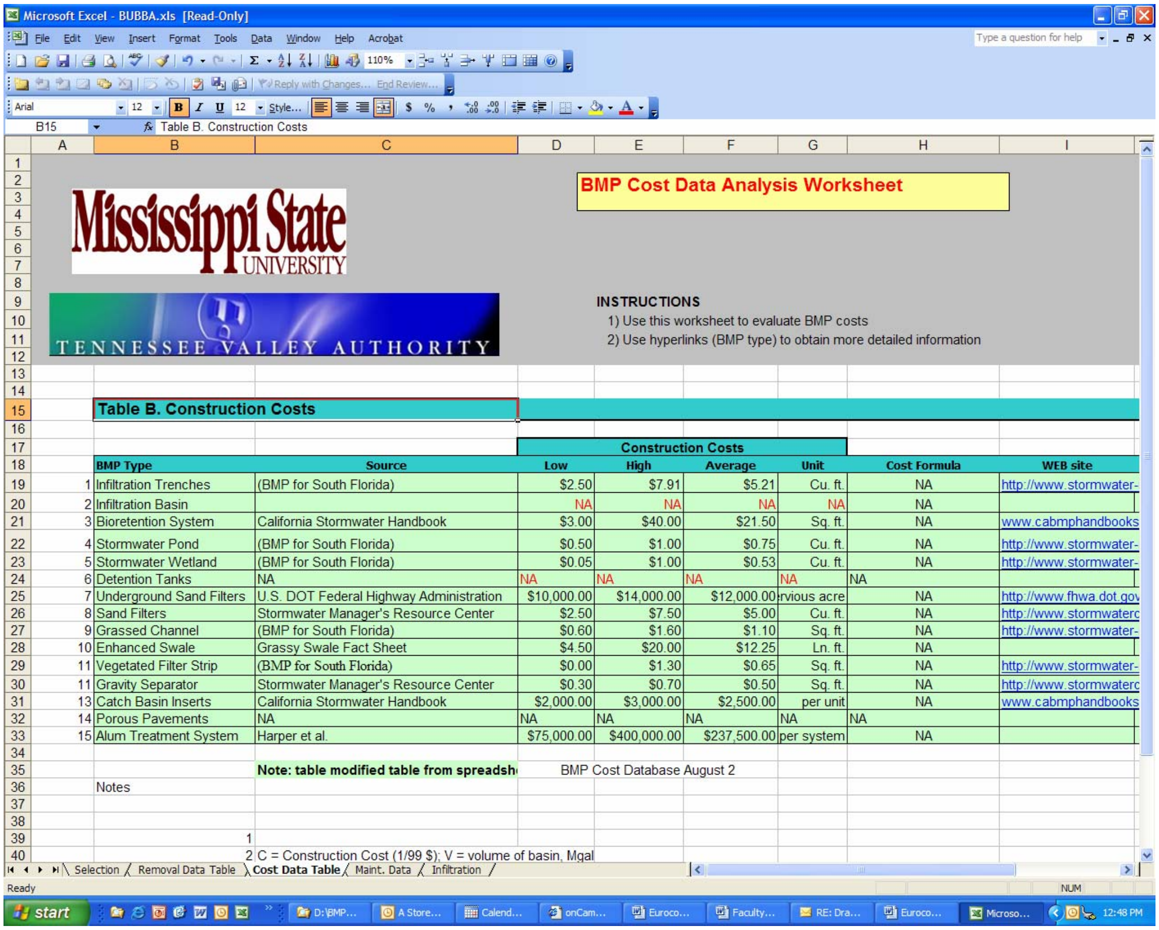


Table B. Construction Costs

	BMP Type	Source	Construction Costs Low	High	Average	Unit	Cost Formula	WEB site
1	Infiltration Trenches	(BMP for South Florida)	$2.50	$7.91	$5.21	Cu. ft.	NA	http://www.stormwater-
2	Infiltration Basin		NA	NA	NA	NA	NA	
3	Bioretention System	California Stormwater Handbook	$3.00	$40.00	$21.50	Sq. ft.	NA	www.cabmphandbooks
4	Stormwater Pond	(BMP for South Florida)	$0.50	$1.00	$0.75	Cu. ft.	NA	http://www.stormwater-
5	Stormwater Wetland	(BMP for South Florida)	$0.05	$1.00	$0.53	Cu. ft.	NA	http://www.stormwater-
6	Detention Tanks	NA	NA	NA	NA	NA	NA	
7	Underground Sand Filters	U.S. DOT Federal Highway Administration	$10,000.00	$14,000.00	$12,000.00	rvious acre	NA	http://www.fhwa.dot.gov
8	Sand Filters	Stormwater Manager's Resource Center	$2.50	$7.50	$5.00	Cu. ft.	NA	http://www.stormwaterc
9	Grassed Channel	(BMP for South Florida)	$0.60	$1.60	$1.10	Sq. ft.	NA	http://www.stormwater-
10	Enhanced Swale	Grassy Swale Fact Sheet	$4.50	$20.00	$12.25	Ln. ft.	NA	
11	Vegetated Filter Strip	(BMP for South Florida)	$0.00	$1.30	$0.65	Sq. ft.	NA	http://www.stormwater-
11	Gravity Separator	Stormwater Manager's Resource Center	$0.30	$0.70	$0.50	Sq. ft.	NA	http://www.stormwaterc
13	Catch Basin Inserts	California Stormwater Handbook	$2,000.00	$3,000.00	$2,500.00	per unit	NA	www.cabmphandbooks
14	Porous Pavements	NA	NA	NA	NA	NA	NA	
15	Alum Treatment System	Harper et al.	$75,000.00	$400,000.00	$237,500.00	per system	NA	

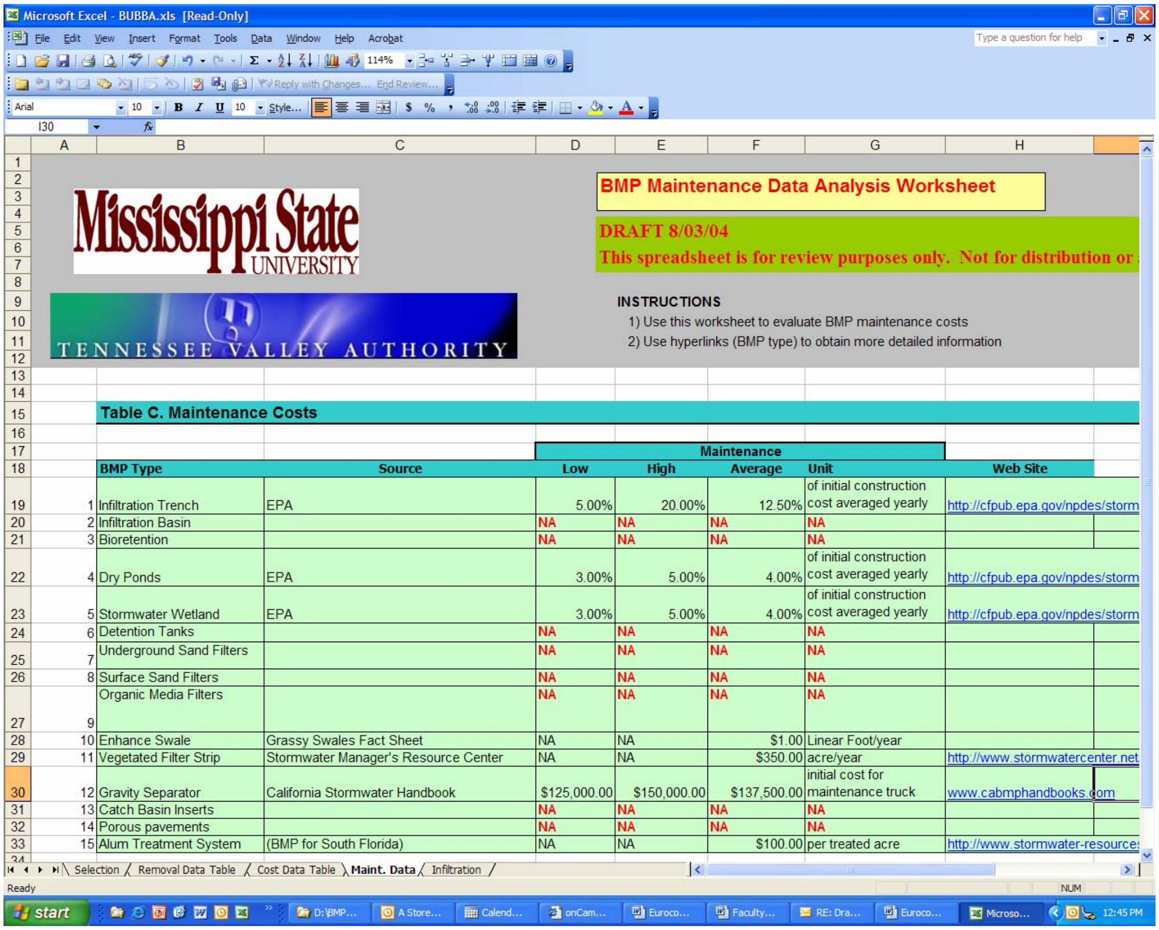
Note: table modified table from spreadsh BMP Cost Database August 2

Notes

1

2 C = Construction Cost (1/99 $); V = volume of basin, Mgal

Figure 4. The Cost Data Table worksheet.



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BMP Maintenance Data Analysis Worksheet

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INSTRUCTIONS

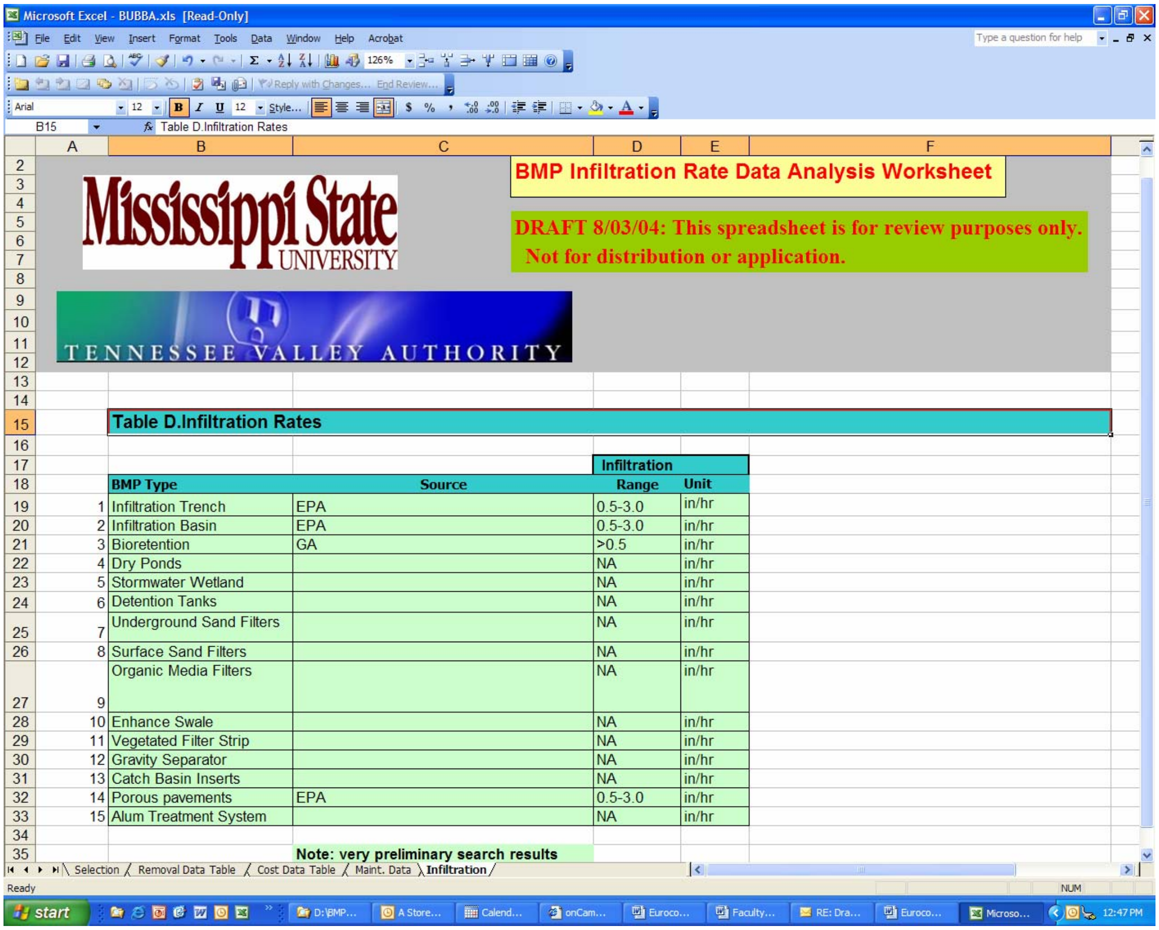
1) Use this worksheet to evaluate BMP maintenance costs

2) Use hyperlinks (BMP type) to obtain more detailed information

Table C. Maintenance Costs

	BMP Type	Source	Maintenance Low	High	Average	Unit	Web Site
1	Infiltration Trench	EPA	5.00%	20.00%	12.50%	of initial construction cost averaged yearly	http://cfpub.epa.gov/npdes/storm
2	Infiltration Basin		NA	NA	NA	NA	
3	Bioretention		NA	NA	NA	NA	
4	Dry Ponds	EPA	3.00%	5.00%	4.00%	of initial construction cost averaged yearly	http://cfpub.epa.gov/npdes/storm
5	Stormwater Wetland	EPA	3.00%	5.00%	4.00%	of initial construction cost averaged yearly	http://cfpub.epa.gov/npdes/storm
6	Detention Tanks		NA	NA	NA	NA	
7	Underground Sand Filters		NA	NA	NA	NA	
8	Surface Sand Filters		NA	NA	NA	NA	
9	Organic Media Filters		NA	NA	NA	NA	
10	Enhance Swale	Grassy Swales Fact Sheet	NA	NA	$1.00	Linear Foot/year	
11	Vegetated Filter Strip	Stormwater Manager's Resource Center	NA	NA	$350.00	acre/year	http://www.stormwatercenter.net
12	Gravity Separator	California Stormwater Handbook	$125,000.00	$150,000.00	$137,500.00	initial cost for maintenance truck	www.cabmphandbooks.com
13	Catch Basin Inserts		NA	NA	NA	NA	
14	Porous pavements		NA	NA	NA	NA	
15	Alum Treatment System	(BMP for South Florida)	NA	NA	$100.00	per treated acre	http://www.stormwater-resources

Figure 5. The Maintenance Data Table worksheet.



BMP Infiltration Rate Data Analysis Worksheet

DRAFT 8/03/04: This spreadsheet is for review purposes only. Not for distribution or application.

Table D.Infiltration Rates

	BMP Type	Source	Infiltration Range	Unit
1	Infiltration Trench	EPA	0.5-3.0	in/hr
2	Infiltration Basin	EPA	0.5-3.0	in/hr
3	Bioretention	GA	>0.5	in/hr
4	Dry Ponds		NA	in/hr
5	Stormwater Wetland		NA	in/hr
6	Detention Tanks		NA	in/hr
7	Underground Sand Filters		NA	in/hr
8	Surface Sand Filters		NA	in/hr
9	Organic Media Filters		NA	in/hr
10	Enhance Swale		NA	in/hr
11	Vegetated Filter Strip		NA	in/hr
12	Gravity Separator		NA	in/hr
13	Catch Basin Inserts		NA	in/hr
14	Porous pavements	EPA	0.5-3.0	in/hr
15	Alum Treatment System		NA	in/hr

Note: very preliminary search results

Figure 6. The Infiltration Data Table worksheet.

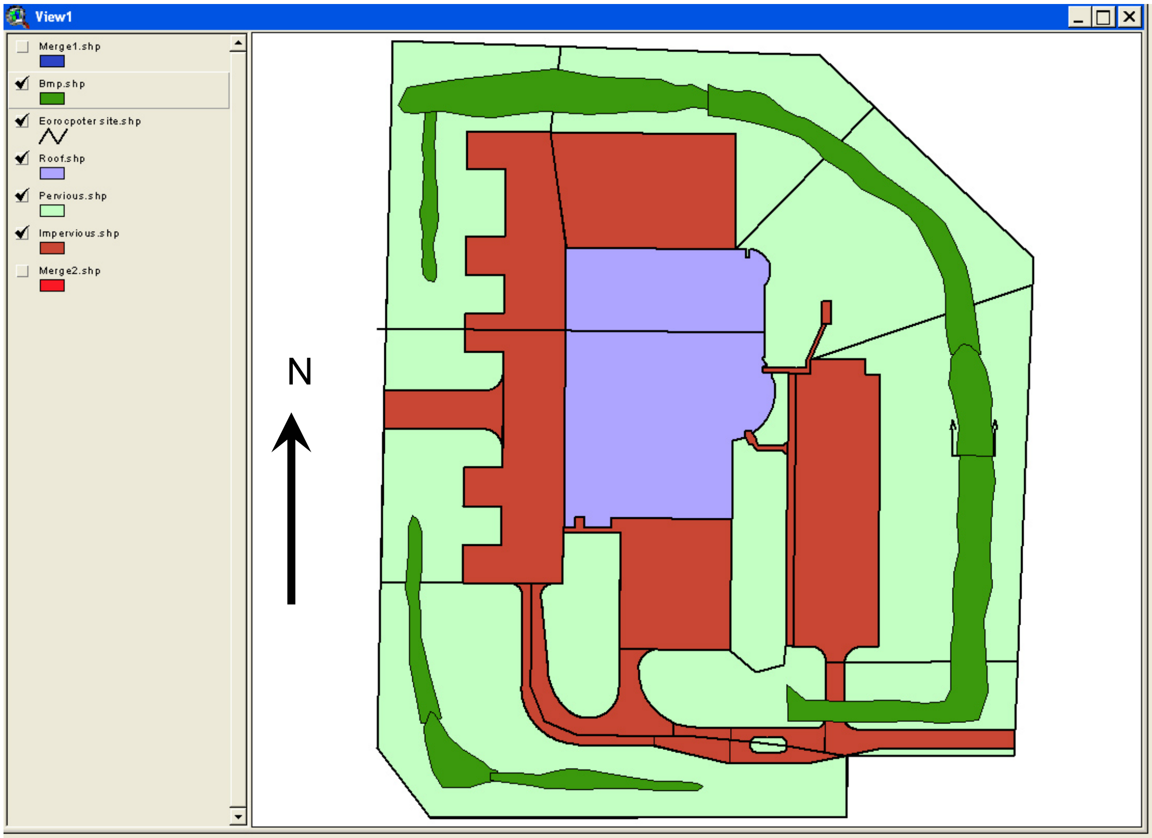


Figure 7. Eurocopter site in Arcview

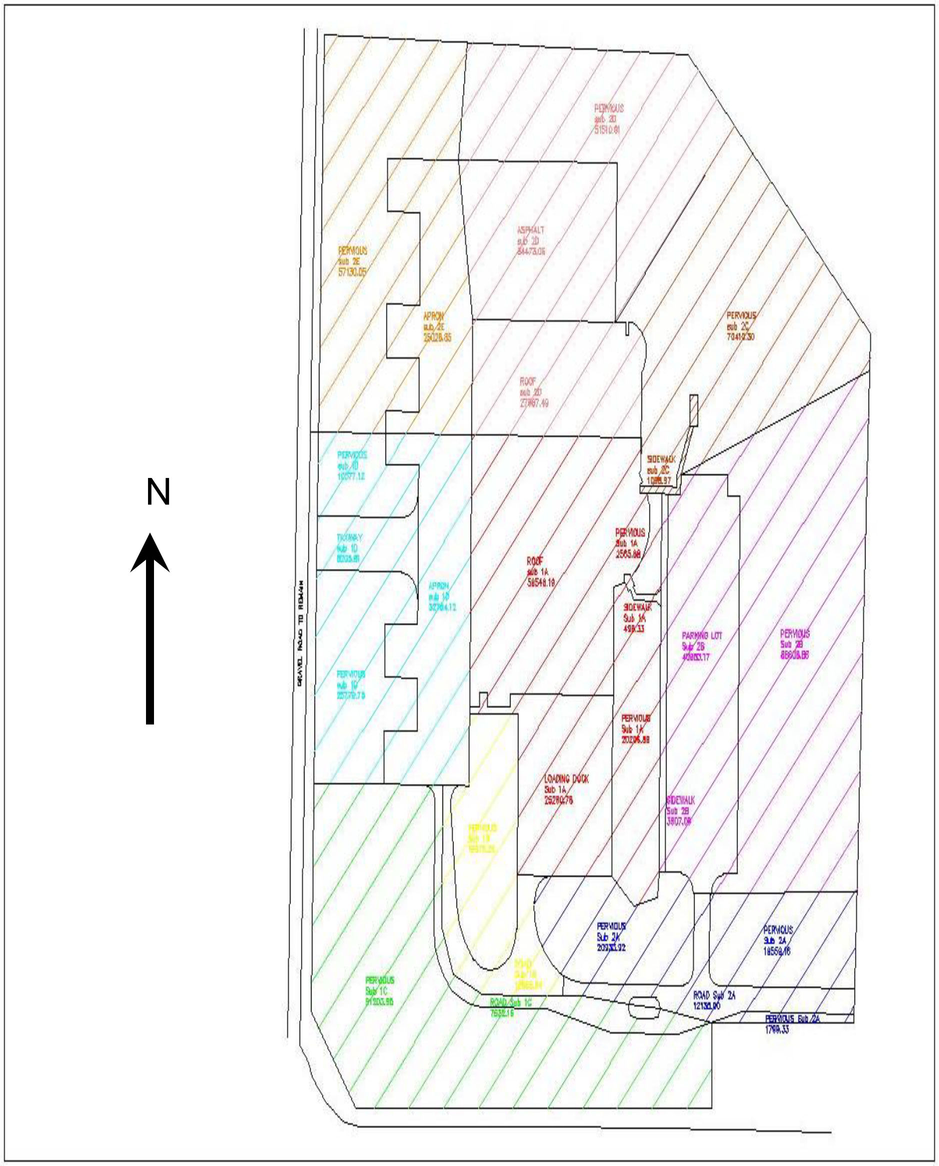


Figure 8. Eurocopter development with sub-catchments labeled.

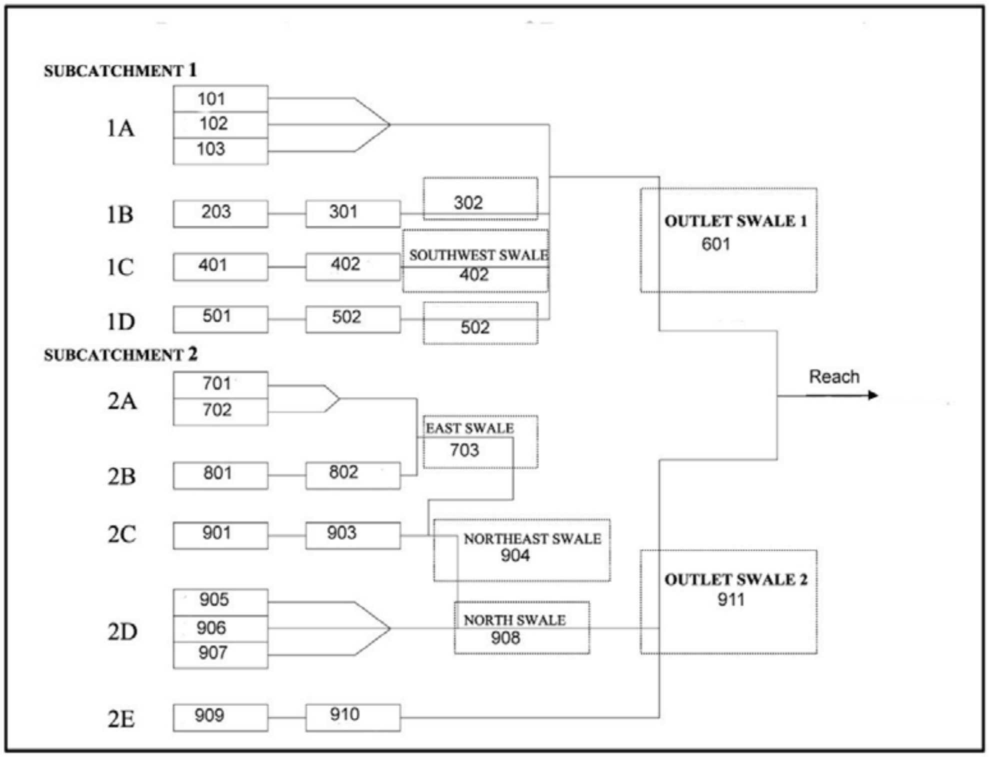


Figure 9. HSPF segment numbering for the Eurocopter site.

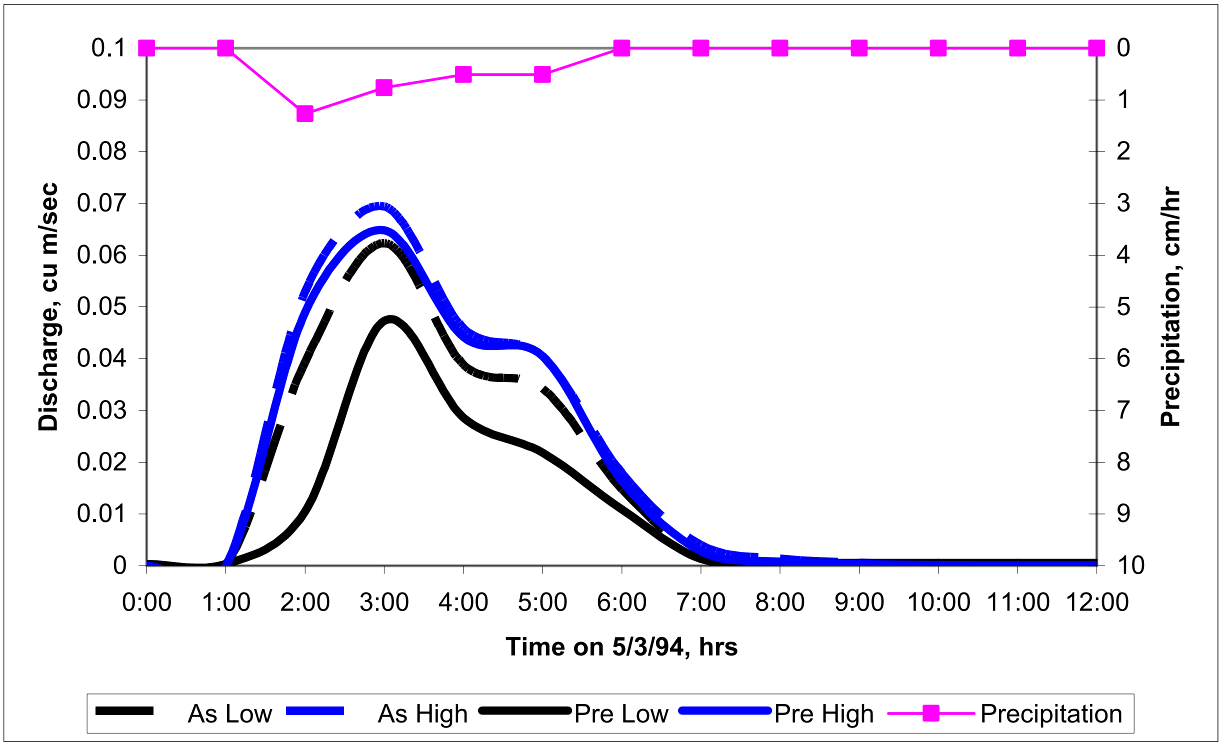


Figure 10. Comparison of HSPF model results for the Predevelopment and As-Built Conditions using high and low estimates of parameters.

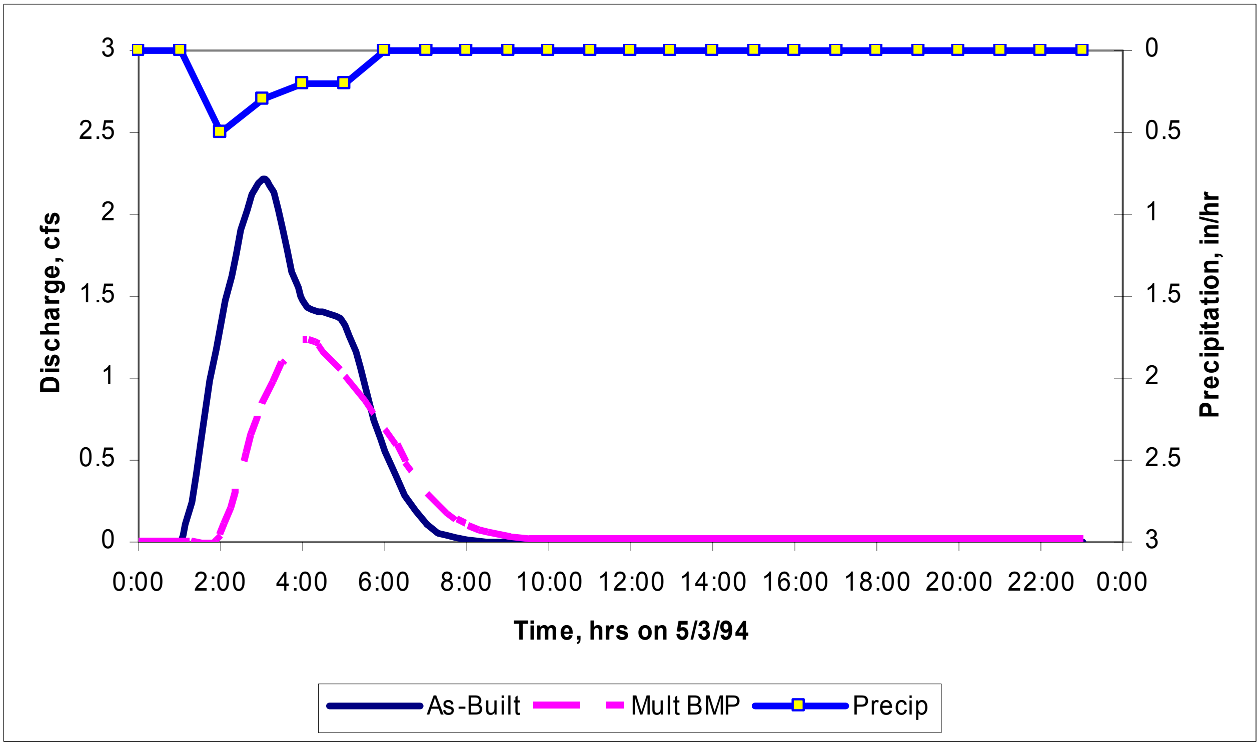


Figure 11. Comparison of HSPF model results for the as-built conditions with and without multiple BMPs.

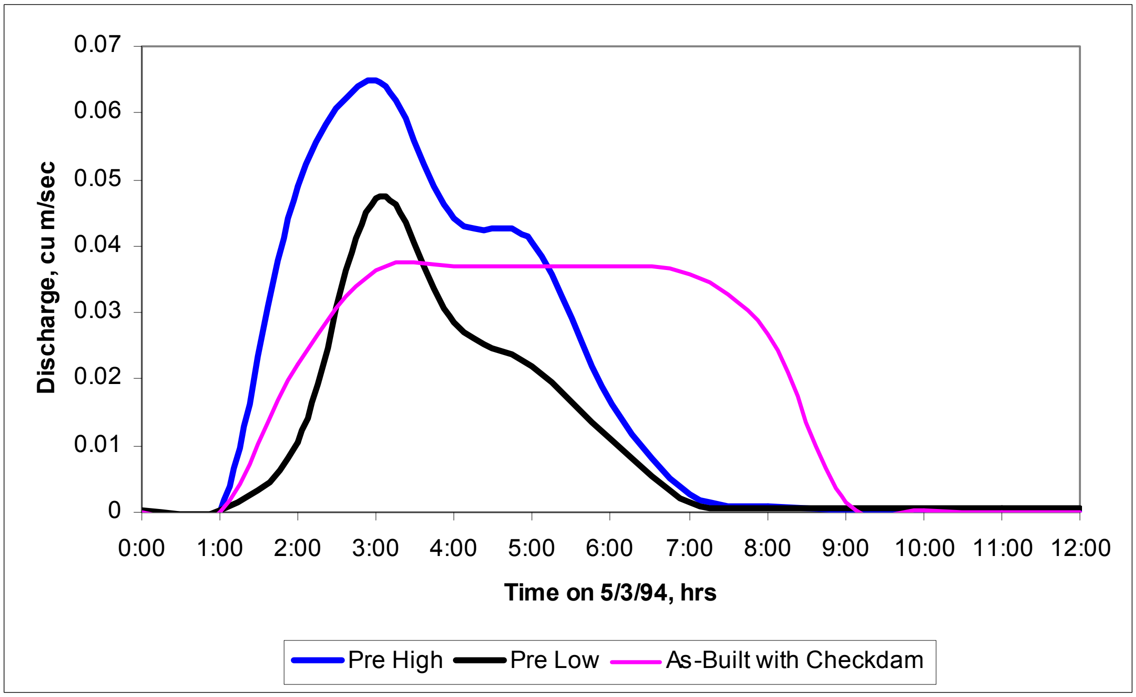


Figure 12. Comparison of HSPF model results for the pre-development and as-built conditions with a check dam in the outlet channel.