STORMWATER GEOGRAPHIC INFORMATION SYSTEM APPLICATIONS IN CENTRAL FLORIDA

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ABSTRACT

Recent National Permit Discharge Elimination System (NPDES) permits issued by the United States Environmental Protection Agency (USEPA) for municipal separate storm sewer systems (MS4) require some level of routine inspection and maintenance for stormwater systems. Typically, a municipality is required to maintain an internal record keeping system to track inspection and maintenance activities. In order to accomplish this, a municipality needs to have a good inventory of the maintained stormwater system including structure geometry and condition information. Historically, municipalities have relied on primary system inventories completed during a stormwater master planning process or subdivision record drawings. If a municipality relies solely on master plan inventories, the development of a municipal-wide inventory may take many years and is unlikely to be completed in time to help with NPDES permit compliance (i.e. structure ownership, structure maintenance, dry weather field screening of outfalls, etc.).

For these reasons, several municipalities in central Florida have initiated programs to inventory the stormwater structures using a Geographic Information System (GIS) tailored to their specific needs. These municipalities will select appropriate stormwater structure maintenance levels of service (LOS) based on their stormwater structure inventories. The associated GIS will be used in the development and implementation of maintenance programs to facilitate meeting NPDES permit requirements as well as to increase the effectiveness and operable life of stormwater facilities. This paper discusses the development of a stormwater GIS for Brevard County, Florida and how this GIS is being used to enhance their maintenance program and help prepare for their expected NPDES permit requirements.

INTRODUCTION

EPA recently issued draft amendments to the Clean Water Act in Section 40 Code of Federal Regulations (40 CFR) Subsection 122.26 to include small municipal separate storm sewer systems (MS4's) into the NPDES permit program. The state of Florida will administer the stormwater NPDES permit program in the near future and will likely issue a state-wide general permit for small MS4's. Small municipalities will be able to gain coverage through the general permit via a Notice of Intent. The fundamental goal of the permit will be that they develop a stormwater

management program which controls stormwater pollution to the maximum extent practical. As a minimum, the management program must have the following aspects:

- Public education and outreach;
- Public involvement and participation;
- Illicit discharge detection and elimination;
- Construction discharge controls;
- Runoff retention for development and significant redevelopment; and,
- Municipal operations and pollution prevention.

Although the permitting requirements will not be as stringent as those for more populous counties, it is clear from review of the permits being issued around the state that many municipalities will be required to perform additional maintenance on their stormwater systems. Another expected requirement will be documentation of maintenance activities and a demonstration that the maintenance program is effectively working to reduce pollutant loads to waters of the United States.

For most small municipalities, a routine maintenance program for their entire stormwater system would be cost prohibitive and probably unnecessary to meet EPA requirements. However, it will be necessary to craft a maintenance program that will meet local demands and future NPDES permit conditions for the MS4. For these reasons, a stormwater Operations and Maintenance (O&M) program structured to provide inspections of all facilities according to a fixed schedule and to provide maintenance as needed may be more appropriate. A routine inspection program will function as a routine maintenance program but will cost significantly less than a routine maintenance program. Routine maintenance schedules can still be used as guidelines for the overall program. This is an efficient way to manage staff time and work efforts while still meeting the intent of the EPA NPDES program.

The remainder of this paper discusses O&M levels of service and how municipalities in Central Florida are using Geographic Information Systems (GIS) to improve O&M programs including documentation of maintenance completed.

LEVELS OF SERVICE

Although the operable life of a stormwater facility is generally expected to last several decades or more, lack of maintenance resulting in overgrown vegetation, accumulated sediment and debris, and deteriorated structures can greatly reduce effectiveness. Without regular operation and maintenance programs, these facilities may not store, treat, or convey stormwater according to their design, and may require frequent repair or even replacement. Regular maintenance will allow facilities to operate as designed for their maximum lifetime, enabling optimum flood control and water quality treatment as well as demonstrating to the public that stormwater capital investments are being protected in a systematic, responsible and cost-effective manner. However, fiscal constraints often limit the LOS that can be appropriately provided in a specific area.

The highest LOS is a routine O&M program including a scheduled inspection and maintenance program for all stormwater facilities including ponds, culverts, inlets, ditches, and primary channels. A routine O&M program requires a complete inventory of stormwater structures for which a municipality has maintenance responsibility. Additionally, a municipality

needs to have access to these structures and have defined maintenance protocol based upon structure type. This LOS requires a municipality to be proactive in addressing potential problems such as cracks in headwalls or box culverts which could lead to deterioration of rebar and the ultimate failure of the structure. In Florida, such routine O&M programs are rare at best and in most cases unnecessary. It has been our experience that most programs are somewhere between purely reactionary, addressing problems only when they become critical, and the routine O&M program described above. The advantage of a more rigorous O&M program is that stormwater facilities are more likely to operate as designed.

Before a LOS can be defined, a municipality must have a good inventory of the stormwater structures it is responsible for maintaining. Historically, stormwater maintenance has been reactionary (complaint driven) in nature with no effort on identification and mapping of stormwater structures under the maintenance responsibility of a municipality. Therefore, decisions regarding the balance between maintenance costs and LOS provided could not be effectively addressed. To address this issue, several Central Florida municipalities have initiated stormwater structure inventory programs using GIS tools. Once the inventories are completed and LOS objectives defined, the stormwater GIS can be used for maintenance planning and reporting.

STORMWATER GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENT

Brevard County is striving to develop a county-wide stormwater GIS to assist with stormwater planning and maintenance activities and making LOS decisions. As part of the Brevard County Stormwater Needs Assessment, Camp Dresser & McKee Inc. (CDM) compiled stormwater structure data and provided geographic-based information to the Brevard County Surface Water Improvement Division in a GIS, using Microsoft Access97© and ArcView Version 3.1©. Brevard County intends to use this GIS stormwater inventory to help develop and implement an ongoing stormwater facility maintenance program to their desired LOS and meet the requirements of their NPDES MS4 permit.

CDM initially developed drainage basin and primary stormwater management system GIS data layers (coverages) of the County using existing data sources. These coverages provided the foundation for the subsequent development of a stormwater structure GIS coverage. Discussions of the development of these coverages and the linked database are summarized below.

Base Map

The digital base map was based on existing coverages obtained from the Brevard County GIS Department and St. John's River Water Management District (SJRWMD). The digital map data obtained included roadway center lines, municipal boundaries, county commission districts, parcel boundaries, rivers, streams, and the edge of water bodies. CDM added basin boundaries and primary stormwater management system coverages to the County base map. The SJRWMD-defined major basin boundaries were used as the starting point for refining basin boundaries to a level of detail suitable for the County's O&M program. Specifically, the original SJRWMD basin delineations do not reflect impacts to the natural stormwater conveyance systems east of Interstate 95 from development. Consequently, CDM revised or subdivided major basin boundaries using available topographic information, completed stormwater master plans, and aerial photographs. The basin coverage was further refined as needed using data gathered under the stormwater structure field inventory.

Primary Stormwater Management Systems (PSWMS)

The PSWMS GIS coverage provides the stormwater network that conveys runoff to receiving water bodies (including waters of the United States). The PSWMS is generally defined as structures with equivalent diameters greater than 24-inches and/or facilities the County has clear maintenance responsibility for. The existing USGS hydrology coverage was the starting point for defining the PSWMS because it showed streams, ditches, canals, and shorelines. CDM used the major and minor attributes of the digital hydrology coverage to create a subset of the streams, canals, and ditches estimated to be part of the County's PSWMS. Adjustments to this coverage were also made using aerial photographs and completed stormwater structure inventories.

Stormwater Inventory GIS Design

In a parallel effort to the development of the digital map coverages, CDM worked with the County to define the types of structures and associated attribute data to be included in the Stormwater Inventory GIS. The types of structures included are summarized in **Table 1**.

For each structure type, associated attribute data were defined including location information (commission district, section-township-range, basin, state plane coordinates), geometric characteristics (diameters, lengths, elevations, etc.), physical condition descriptors, construction date, planned inspection frequency, last inspection date, and next scheduled inspection date. Once defined, a database was developed using Microsoft Access97©. The database was then linked to the GIS coverages developed in ArcView©.

In order to link the GIS coverages with the associated database tables, each structure inventoried was assigned a unique identifier. The unique identifier developed for the County included a three-digit numeric value representing each map tile (grid) defined for the project, followed by a two-digit alphanumeric value representing the structure type (see Table 1), and finally followed by a four-digit numeric value assigned by the County based upon the number of each structure type identified on a map tile (ascending order, 0001, 0002, etc.).

Table 1 Types of Stormwater Structures Included in Brevard County GIS		
Structure Type	**Structure Code**	**Coverage Type**
Bridge	BR	Point
Curb Inlet	CI	Point
Control Structure	CS	Point
Culvert	CU	Line
End Structure	ES	Point
Grated Inlet	GI	Point
Manhole	MH	Point
Open Channel	OC	Line
Outfall	OF	Point
Pond	PO	Point
Pump Station	PS	Point
Storm Sewer	SS	Line

Field Inventory and Database Population

Two representatives from the Brevard County Surface Water Improvement Division provided the field inventory work. To accomplish this task, the field crews inventoried the PSWMS on a section by section basis. Structures were hand drawn on existing parcel maps of the County plotted out by section. For each structure, the field crews took appropriate photographs and completed the data form shown in **Figure 1**. The data form was developed from the data dictionary previously described. Information from the forms were manually transferred to the Microsoft Access97© database and linked to ArcView©.

As an alternative to the "paper data form", CDM has designed digital data forms that can be used with a palm top computer. This type of system was implemented for the City of Nashville, Tennessee, as part of its stormwater inventory GIS. This type of system requires more of an up-front capital investment but eliminates completing paper forms in the field and then manually entering information from the paper forms into the master database. Information is entered into the palm top computer in the field and then electronically transferred to the master database. For large inventory efforts, the digital forms may be more cost effective.

The final GIS coverages were linked with the database using SQL Connect, which is a standard Arcview tool. A representative view of the linked GIS is presented on **Figure 2**. The three main components of the display are the main view, the overview to the right, and attributes tables at the bottom of the screen (database). The main view can be used to zoom in on areas of interest and

select specific structures. The overview window highlights the relative location of the main view on the base map. Information stored in the database for a selected structure can be displayed on the attribute tables shown at the bottom of the figure.

CONCLUSION

Once a stormwater GIS is defined and populated, a municipality can use the information to define a desired LOS and costs. CDM has defined the LOS criteria for O&M activities shown in **Table 2** to classify existing maintenance on stormwater facilities and for setting O&M goals. These goals can differ between drainage basins and structure types based on the characteristics of each system. In general, the LOS goal for a rural watershed may be less than the LOS goal for an urban watershed without having a significant negative impact on flooding or water quality. Achieving desired water quantity and quality goals in an urban system may require LOS A.

Table 2
Brevard County Stormwater Needs Assessment
Operation and Maintenance Level of Service

Level of Service (LOS)	Operation & Maintenance (O&M)
A	Routine Inspection and Maintenance
B	Routine Inspection with Specific Routine Maintenance
C	Routine Inspection with Inspection-Based O&M
D	Reaction/Complaint-Based O&M
E	No Service

LOS A designates a system receiving a routine maintenance program of the stormwater facilities based on the typical maintenance schedule for each facility type.

LOS B designates a system with specific facilities receiving routine maintenance and the remaining facilities receiving inspection-based maintenance.

LOS C designates a system receiving routine inspections with maintenance performed based on the results of the inspections.

LOS D designates a system which receives maintenance strictly as a result of complaints.

LOS E designates a system receiving no maintenance.

Using the stormwater inventory GIS, a municipality can assign a LOS to each structure inventoried. Each structure LOS can be assigned a unit maintenance cost based upon an assumed inspection and maintenance frequency. The GIS reporting features can then be used to query this information to determine an overall planning level program cost for a selected LOS. Assigned LOS criteria can then be adjusted until an affordable and implementable O&M program is developed.

As previously discussed, a stormwater inventory GIS can be a useful tool in managing O&M

activities and adjusting these activities to meet a desired LOS. The system described in this paper provides Brevard County with desktop access to its PSWMS by showing drainage patterns, structure locations and attribute data, and showing stormwater structure inspection and completed maintenance dates. The system can be used to assist with O&M activity planning, documentation of stormwater structure inspection and maintenance activities necessary for NPDES permit requirements. Also, annual evaluations of the accomplishments of the program can be performed using the GIS (i.e., structure condition versus inspection/maintenance frequency) and ineffective programs can modified. Similar systems are currently being developed for Seminole County and Volusia County to assist with their O&M and NPDES programs.

Brevard County Structure Inventory Field Sheet

Date

Field crew

Plan view

N

Location:

Grated Inlets

Map ID	Sump	Sediment Device	Grate Length (in)	Grate Width (in)	Elevation (FT, NGVD) Top	Elevation (FT, NGVD) Bottom	Condition	GPS (X/Y)
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	
	Yes No	Yes No					Good Fair Poor	

Curb Inlets

Map ID	Access*	Sump	Sediment Device	Curb Inlet Length (in)	Curb Inlet Width (in)	Elevation (FT, NGVD) Inlet	Elevation (FT, NGVD) Bottom	Condition	GPS (X/Y)
		Yes No	Yes No					Good Fair Poor	
		Yes No	Yes No					Good Fair Poor	
		Yes No	Yes No					Good Fair Poor	
		Yes No	Yes No					Good Fair Poor	
		Yes No	Yes No					Good Fair Poor	
		Yes No	Yes No					Good Fair Poor	

* Manhole, Grate (no access), Grate (Access), None

Manholes

Map ID	Baffle Box	# of Chambers	Shape	Material	Elevation (FT, NGVD) Top	Elevation (FT, NGVD) Bottom	Condition	GPS (X/Y)
	Yes No		Circ Rect Irreg	Conc Brick Lined				
	Yes No		Circ Rect Irreg	Conc Brick Lined				
	Yes No		Circ Rect Irreg	Conc Brick Lined				
	Yes No		Circ Rect Irreg	Conc Brick Lined				
	Yes No		Circ Rect Irreg	Conc Brick Lined				
	Yes No		Circ Rect Irreg	Conc Brick Lined			Good Fair Poor	
	Yes No		Circ Rect Irreg	Conc Brick Lined			Good Fair Poor	

Figure No. 1a
Field data sheet (front)

End Structures/Outfalls

Map ID	Type*	Headwall Type	Material**	Condition	Receiving Water***
	ES OF			Good Fair Poor	
	ES OF			Good Fair Poor	
	ES OF			Good Fair Poor	
	ES OF			Good Fair Poor	
	ES OF			Good Fair Poor	
	ES OF			Good Fair Poor	

* Type choices: Headwall; Headwall/Grate; Mitered; Mitered/Grate; Grate; Interconnect; None; and Other

** Material choices: Sand-Cement (Rip-Rap); Concrete; Brick; Coquina; and Other

*** Receiving water choices (applicable for outfalls): Indian River (IR); Banana River (BR); Eau Gallie River (EGR); Sebastian River (SR); St. Johns River (SJR); Sykes Creek (SC); Crane Creek (CC); Turkey Creek (TC); M-1 Canal (M-1); South Lake (SL); Washington Lake (WL); Atlantic Ocean (AO); Unnamed Creek (creek); Unnamed Canal (canal), Unnamed Pond (pond).

Storm Sewers/Culverts

Map ID	Type	Shape*	Dimensions Diam or H/W	Material**	Inverts Upstream	Inverts Downstream	Condition	Length (ft)
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	
	SS CU						Good Fair Poor	

* Shape choices: Circular; Arch; Oval; Rectangular; and Irregular.
Also specify if French Drain

** Material choices: Reinforced Concrete Pipe (RCP); Corrugated Metal Pipe (CMP); Asphalt Coated CMP (ACCMP); Corrugated Aluminum Pipe (CAP); ADS plastic pipe (ADS); PVC; Iron; Asbestos Concrete Pipe (ACP); Vitrified Clay Pipe (VCP); and Concrete-lined (CL).

Open Channels

Map ID	Type*	Shape**	Material*** Sides	Material*** Bottom	Width (ft) Bank	Width (ft) Bottom	Elevation (NGVD) US	Elevation (NGVD) DS	Condition	Length (ft)
									Good Fair Poor	
									Good Fair Poor	
									Good Fair Poor	
									Good Fair Poor	
									Good Fair Poor	
									Good Fair Poor	
									Good Fair Poor	

* Type choices: natural or man-made.

** Shape choices: Trapezoid; V-shaped; Irregular; or natural.

*** Material choices: Grass; Sand-Cement; Bare Geosynthetic; Brush-lined; Concrete; or other.

Control structures

Map ID	Type*	Material**	Length	Dimensions Diam or H/W	Skimmer	Grate	Weir type	Condition
					Y N	Y N		Good Fair Poor
					Y N	Y N		Good Fair Poor

* Diversion box, Riser/standpipe, Mod inlet inline, Manhole w/weir, Pond outfall, Flashboard, Unknown

** concrete, iron, brick, concrete-lined, other

*** circular, rectangular, oval, V. arch, trapezoid, irregular, none

Bridge

Map ID	Road	Width	Length	Deck	Material* Pier	Wingwall	Pier Number	Pier Spacing	Scour	Condition
									Y N	Good Fair Poor

* Concrete, asphalt, brick, iron, other

Pond

Map ID	Top of bank Elevation	Area	Fence
			Y N

Figure No. 1b
Field data sheet (back)

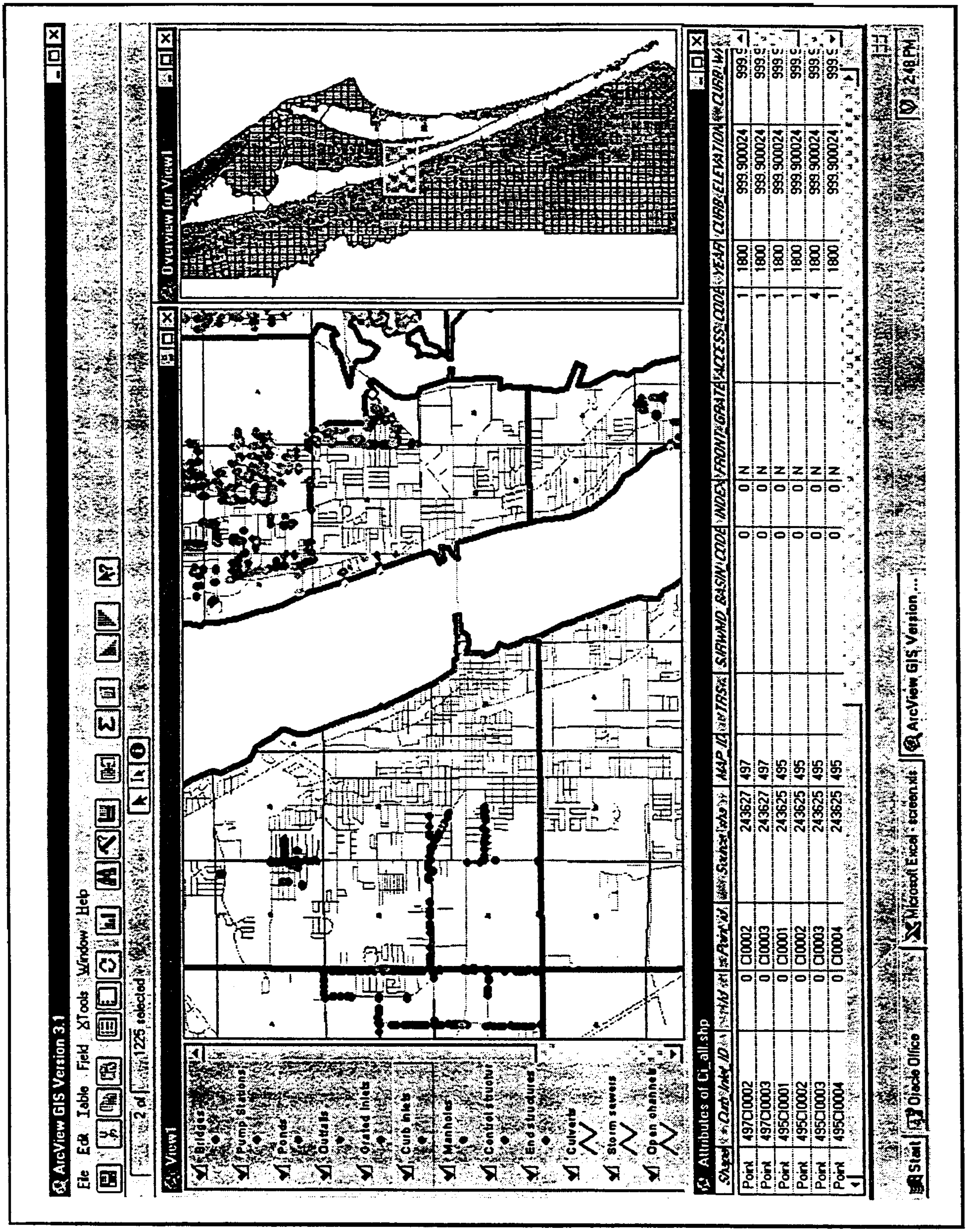

Figure No. 2

Stormwater structure GIS screen example