# Erie County Mobile GIS Implementation: Populating the Sewer Inspection Database

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# Abstract:

Erie County Department of Environment and Planning, Division of Sewerage Management (DSM) initiated a GIS program in 2002 with the goal of mapping all existing DSM assets and creating a database of asset information. After two years of building the GIS and data collection, it was time to give the database to field inspection staff for detailed verification and collection of asset information. This paper will explore the obstacles, challenges, and rewards associated with rolling out Mobile GIS to a "technologically challenged" sewer inspection staff. It will demonstrate how the DSM uses ArcInfo, ArcView, ArcPad, and ArcIMS software; GPS technology; and Pocket/Tablet PCs to create custom e-forms within ArcPad to edit and locate sewer asset information. It will detail how Mobile GIS is used to assist DSM Maintenance/Inspection staff in the collection of data to be used in the planning, development, and implementation stages of our CMOM and Inflow and Infiltration programs.

#### Introduction:

Erie County's Division of Sewerage Management (DSM) is a division of the County's Department of Environment and Planning. The DSM is responsible for the planning, design and construction, and subsequent financing, operation and maintenance of the County's sanitary sewer This includes the facilities of the six (6) Erie facilities. County Sewer Districts (ECSD), the Erie County/Southtowns Sewage Treatment Agency, and County owned facilities.



Figure 1 – Erie County Sewers

The Division of Sewerage Management is responsible for over 850 miles of sewer, 82 sewage pumping stations, 426 low pressure grinding units, 5 overflow retention facilities, and 8 advanced wastewater treatment facilities.

The Districts provide sanitary sewer services to communities within their respective boundaries. The Districts are responsible for the construction and maintenance of lateral and interceptor sanitary sewer systems and wastewater treatment facilities. In Erie County Sewer District 6, the District is also responsible for the storm sewer system.

The Erie County Sewer District's are governed by Boards of Managers appointed by the County Executive and confirmed by the Erie County Legislature.

The DSM continues to grow and currently maintains over 30,000 collection system assets in addition to the wastewater treatment facility assets with a full-time staff of over 200, and an IT staff of two (2).

### GIS Initiative:

In late 2001, there was nothing. Scattered across Erie County were paper maps, scanned TIFF images, and six (6) CAD basemaps representing data for each of the sewer districts. There was a copy of ArcView 3.2 in a box.

There were a few relative shapefiles provided to us by the Erie County GIS group, and the Erie County Water Authority (ECWA) for centerlines, parcels, hydrology, airports, poles, pavement, buildings, etc. This was enough to get a basemap started.

The DSM officially began their GIS program in April 2002 by incorporating various CAD drawings into one Erie County CAD basemap. There were many problems with the conversion, including projection issues and consistency errors in the CAD and

electronic drawings. CAD drawings were brought into ArcGIS where individual CAD layers were converted into shapefiles.

The first year of GIS development included building a basic GIS basemap, fixing most consistency errors, and developing and populating asset databases.

GPS field work began in May 2003, and will be finished by December 2005. Almost 30,000 collection system assets have been GPS'd, and the GIS basemap adjusted to accurately depict the sewer collection system. All GPS data collection was performed by seasonal interns, accompanied by a district field staff member. During GPS data collection almost 2,000 manholes were eliminated from the existing basemap, and approximately 3,000 manholes were added.

#### **Current and Future Projects:**

Current and future projects planned for the DSM include a move from our existing personal Geodatabase format to an enterprise database using ArcSDE and Oracle. We've been informed of the need to upgrade our versions of ArcView to ArcEditor in anticipation of this move. While this upgrade from ArcView to ArcEditor does not come cheap (approximately \$4,200), it is necessary as editing cannot be performed in an SDE environment with ArcView.

The DSM is currently using an ArcIMS website to deploy GIS information to division staff not trained to use GIS. The existing ArcIMS Interface was upgraded in April 2005 by the Erie County OGIS staff. The Interface is modeled after the official Erie County ArcIMS web interface (<u>http://erie-gis.co.erie.ny.us/website/erie\_help/help.htm</u>).

The DSM is currently working on an automated Underground Facility Protection Organization (UFPO) Program, Dig Smart, developed by Bergmann Associates. The program uses ArcGIS and our existing GIS data sets to automate the UFPO workflow. The program geocodes incoming addresses, and shows DSM assets within a 200 foot buffer around the address. Once the incoming ticket from Dig Safely New York is staked out, the contractor is automatically notified if they provide an email address or Fax number. While the program contains a lot of bugs, it's working very well.

Lastly, the DSM has created a custom built Intranet portal to all IT projects. The portal was built based on a ColdFusion web application server. Future plans include incorporating an ArcIMS interface into the existing Intranet allowing the Intranet to seamlessly integrate into the ArcIMS application.

#### Mobile GIS:

What is Mobile GIS? ESRI defines mobile GIS as "A mobile geographic information system (GIS) integrates three essential technologies: Global positioning system (GPS) technology, GIS software, and handheld communication devices. By bringing these technologies together makes the enterprise database directly accessible to field-based personnel—anywhere and anytime. Mobile GIS enables organizations to add real-time information to their enterprise database and applications, speeding analysis, display, and decision making. "

The DSM chose to incorporate the concept of Mobile GIS because after two years of building the foundation for an enterprise GIS, the need to field verify the existing data was the next logical step in the project development. Even though a paper map, as-built drawing, or 2-year old ortho photo says an asset exists, that does not mean it's actually there or the information about the asset is correct.



Figure 2 – GPS Data Collection

#### Mobile GIS – Hardware/Software:

The DSM chose Trimble and iPAQ hardware products for our Mobile GIS system. Mobile GIS data collection was performed with two units, a HP iPAQ 2210, and a Trimble Recon. Both performed exceptionally well, with a few minor issues in performance mostly during cold weather events. For a few Mobile GIS projects, a camera and a digital video camera were used.

To collect GPS information a Trimble ProXR and Trimble GeoXT were used. The Trimble ProXR receiver is a GIS data collection and data maintenance system which provides real-time submeter accuracy. It is essentially a backpack unit providing real-time submeter accuracy with a computer (Pocket PC/GeoXT) as a data collector. The Trimble GeoXT is a standalone submeter (post processed) windows CE unit. It can run Terrasync, and ArcPad, and has been found to be very rugged. During the start of GPS data collection, the GeoXT was used as a data collector, due to issues with the HP iPAQ 2210. We were not able to connect the 2210 to the Trimble ProXR. There have been discussions about Bluetooth solutions to this problem, but we have not looked into them yet.

The DSM uses ESRI and Trimble's line of GIS and data collection Software for Mobile GIS. We currently use ArcInfo and ArcView for all GIS applications. Data collection software is Trimble's TerraSync Professional, and ESRI's ArcPad. eForms were developed in ArcPad Application Builder. Trimble's Pathfinder Office is used to differentially correct GPS data. We tested Trimble's Mediamapper 3.1-20a for the

Mobile GIS project. And finally data is served up over the DSM's Intranet using ColdFusion as the web application server.

The ability to create Dynamic eForms (electronic forms) in ArcPad Application Builder has brought the inspection process to a new level in terms of quality and quantity of work.

## Dynamic eForms:



Figure 3 – Dynamic eForm

Dynamic eForms are interactive versions of paper forms in a digital format. Once transcribed to an electronic medium the benefits of eForms over traditional paper forms become limitless. Spell checking, interactive drop-down lists, and the ability to link completed forms to geographical points on an interactive map are just of few of the potential features that propel eForms beyond the realm of paper and pencil data collection.

The Erie County DSM had numerous problems with traditional manhole inspection forms which inspired the division to start developing eForms. The most prominent of which were: incomplete forms, illegible handwriting, inconsistent data, transcription errors in database, lost pages, and excessive amounts of paper.

Incomplete forms were by far the largest concern to be addressed. Out of a average 1,800 annual inspections about 30% were incomplete upon submission for review, and about 40% of those were missing vital, such as the manhole number or location, and rendered absolutely useless. Driving out to, locating and inspecting a single manhole in a district covering roughly 500 square miles is time consuming, and with a good 10% of manhole inspections needing to be redone, this proved to be a significant cost in terms of man-hours. This cost was further escalated by the time required to transcribe information from the paper forms to a database, to decipher illegible handwriting, and to normalize the data to maintain consistency in the database.

The concept of eForms was introduced to the DSM and with a mobile GIS initiative already in effect in Erie County the idea was warmly accepted and quickly expanded to use ArcPad to dynamically link inspections with the spatial data of the manholes in the GIS to create an interactive map used for both manhole location and inspection.

With the eForm illegible handwriting and incomplete forms are no longer an issue as data is no longer handwritten and validation rules ensure that the form is completely filled out. The majority of the data fields on the form were created as pull-down lists which significantly shortened the time for filling out the forms and also eliminated the risk of inconsistent data being entered, poor spelling, and extraneous information. Risk

of transcription errors from forms to a database was also eliminated because all data can now be automatically synced to a master database using SQL queries.

Having the eForm tied to a GIS has enormous benefits for data collection. Data can be pulled from many shapefiles and used to automatically populate a sizeable portion of the data, such as street locations, house addresses, parcel numbers, district and minisystem information, and manhole ID numbers. Another benefit is the ability to use the GIS map to quickly locate manholes and sewer lines with respect to streets, monuments, houses, and property lines. Once a manhole is located and inspected a point is added to the inspection layer that overlaps the manhole layer, visibly changing the color of the manhole on the screen and allowing inspection crews to quickly see which manholes have already been inspected and which still need to be, all at a glance.

ArcPad was chosen as the development platform for the DSM's eForms because it has a small footprint on mobile Pocket PC devices. ArcPad has the ability to share data with other ESRI products, and allows the use of VB script to create dynamic interaction with forms and customized validation rules.

Custom toolbars were created for ArcPad to make the most useful tools more easily accessible and to add custom tools specific to the manhole inspection eForm. The inspection tool is used to select a manhole for inspection and then automatically runs buffers to find the nearest street and nearest parcel within 200'. The Inspection tool extracts district, minisystem, and other needed manhole information from the manhole layer and populates a portion of the data fields with this gathered information. An additional tool was also created to allow inspection crews to add spatially located notes to the map containing additional information not related to individual manhole inspections. Tools were also created to easily select, modify, or delete existing inspection points and notes.



Figure 4 – Custom Toolbars

The DSM originally intended to use HP Pocket PCs for eForms applications because of their portability and cost. The Pocket PCs proved themselves in field tests with great performance and exceptional battery life. There were, however, concerns over their durability during sanitary sewer inspection. Therefore, the DSM decided to invest in Trimble Recons before issuing the eForms out to field crews. Recons are Pocket PCs built to military specification and thus much more durable and suitable for field use. Peace of mind over the life expectancy of the units was worth the extra expense. The only problems reported were low-battery life during cold weather events.

The manhole inspection eForm was developed and linked to a shapefile using ESRI's ArcPad Application Builder. Page layout was straightforward and easy to customize with the provided tools and multi-page support with tabs was ideal for fitting all the needed data fields on the small screen of a mobile device. The ability to attach VBS

script files to the form was instrumental in creating customized dynamic validation rules to account for all manhole types. For example if the manhole was marked as having no cone segment then all subsequent fields describing the cone could be deactivated and not required for the form to be validated as complete.

The most challenging part of developing the eForm was the scripting for custom validation rules and dynamic fields. There was very little documentation about ArcPad's COM objects and their interfaces, and virtually no manual for Application Builder to speak of. The user community on the ESRI forums proved to be the most valuable resource for finding answers to development questions. The forum members are very supportive for each other and answers to posts were quick and always helpful.

## Case Studies:

Erie County Mobile GIS projects have been performed in:

- Village of Hamburg (2004)
- Smoke's Creek Outfall Project (2004)
- Village of East Aurora, Town of Aurora (2005)
- Existing Erie County Sewer Districts (2005-Present)

The Village of Hamburg in July 2004 was our initial test case, and from there we were able to test hardware and software products, develop workflow for implementing Mobile GIS, and benchmark the results. The project was performed by the Information Technology (IT) staff and a Village of Hamburg DPW employee who located and opened manholes. Erie County field staff was initially brought into the project, but proved to be a hindrance to the project, and were removed.

The Smoke's Creek project was the most challenging. The DSM was required to GPS the Stormwater outfalls along Smoke's Creek for a SPDES permit. The DSM performed the project with a GeoXT, Canon G3 digital camera, and a HP iPAQ 2210 loaded with ArcPad and a custom eForm to perform Outfall Inspections. Smoke's Creek is a three mile long creek winding through the City of Lackawanna, NY. It is navigable in a few places by boat, but most of the project involved walking through or along the creek. Mobile GIS worked very well for this project. The project could have been done by one person, but due to the safety issues of working around water, an intern was needed. Project deliverables included an updated and accurate GIS map, and Stormwater Outfall assessments in a database. In addition, a GIS map with links to photographs of each Stormwater Outfall was developed.

In March 2005, just before the DSM took over the Operation and Maintenance of the Village of East Aurora and Town of Aurora sewer systems, the IT staff was provided the opportunity to see if we learned anything from the previous year's Mobile GIS study. Using the existing IT staff from the Village of Hamburg project, we increased production 15-25% because of an increased knowledge of the equipment, and the use of dynamic

eForms. The work during the Village of Hamburg project used a first generation, or a static eForm. The development of dynamic eForms increased performance, and made the entire process easier.

We have been slow in rolling out the eForms to our field workers due to a variety of issues. For the most part, we have not started implementing Mobile GIS to all districts because the GPS field work and the QA/QC of the existing maps with as-builts information have not been finished. In addition, the DSM has four unique districts, and each district has pluses and challenges for the implementation of new technologies.

The duration to complete a Mobile GIS project has now been benchmarked. The DSM IT staff is now comfortable with the technology which will allow the ability to train the field staff correctly, and with much needed enthusiasm and confidence for the project.

Currently, eForms for Manhole Inspection and Manhole Repairs are being used in District 2, Northern Region and District 6 offices. Depending on the training and enthusiasm of field staff members in these districts, the results have ranged from "it works" to "I love it!" It has been a struggle to implement this technology, even after showing the benefits. However, once people get used to the hardware, and get over the fear of this new technology, they want more.

#### Mobile GIS Procedures:

The procedure for implementing a Mobile GIS project was straightforward. We looked at what we wanted the project to accomplish.

We wanted Mobile GIS to:

- Accurately model the system as quick as possible
- GPS all assets (Manholes, Cleanouts, Pump Stations, etc.)
- Perform Manhole Inspections using eForms, NOT paper
- Bring all information (spatial, asset) into existing Geodatabase
- Photograph manhole covers, and manhole anomalies for use within Trimble Mediamapper
- Test existing equipment (battery life, durability, etc.)
- Present collected data quickly for immediate analysis

Some of the questions we asked ourselves before we started included: Does Mobile GIS save time? What are the benefits? Are there any problems? Can we incorporate this technology into our existing CMOM and Inflow and Infiltration (I&I) programs? Is it better than existing solutions? Based on our findings, the answer is a definitive yes.

#### Results:

Mobile GIS results were very positive. Developed workflow was easy to follow, and data was easily brought into a database for immediate analysis. The equipment performed exceptionally well, often exceeding expectations. The I&I program benefited the most from the project. Previous Manhole Inspections were written on a paper form, and were accompanied by a lot of quality issues with the data. Dynamic eForms prevented the majority of previous bad work practices. Most important, productivity has increased.

The DSM set benchmarks for performance during the first attempts at using Mobile GIS. The first attempt in the Village of Hamburg produced manhole inspection totals of an average of 70 per day. This was in an urban environment with a crew unfamiliar with the technology. The Smoke's Creek project showed Mobile GIS to be a highly effective data gathering tool in a water environment. Outfall totals weren't analyzed for this project, as moving from one outfall to the next was a factor of the terrain. Sometimes it would take a half hour to wade through chest deep waters to reach the next Outfall location.

Our second attempt at using Mobile GIS in an urban environment exceeded expectations. The project in the Village of East Aurora, and the Town of Aurora were similar to the Village of Hamburg as each was about the same size and area. Manholes were close together, roughly 300 feet apart. Manhole Inspections increased to 90 per day during this project. The best reason for the increase in inspections was due to an increased familiarity with the workflow, and the project hardware.

As for letting existing field crews handle Mobile GIS, there were mixed results. All of the field crews seem to enjoy using the new technology. The field crews are impressed with how easy it is to use, and can see the benefits of using the new technology. However, their inspection numbers are much smaller than the benchmark results. Some districts average 35 a day, some average 20. There are a variety of factors as to why there numbers are so low. Those will be analyzed later in the paper in the human/social engineering section.

Results from analyzing project hardware were excellent. Some of those include:

- Extended battery life excellent with iPAQ 2210. Still above 80% after an 8-hour day of inspections.
- Time efficient. All pull down menus to use the Dynamic eForm.
- Lightweight (handheld or GeoXT solutions)
- Easy to see previous work because all completed manhole inspections represented graphically (allows for route planning).
- iPAQ usable in light rain.
- GeoXT was an excellent GPS data collector. It is lightweight, and had enough battery power for an 8-hour day. Recommended for remote locations and places where climbing or crawling to the asset is required.

 iPAQ 2210's backlit transflective screen allows for clear screen visibility in shade and direct sunlight. If possible, Screens of this type should be purchased for any outdoor work.

Problems were few during our work, but they included:

- iPAQ connection problems to Pro XR prompted the use of a GeoXT as a data collector. We tried everything to make it work, and it wouldn't.
- All electronic hardware had battery issues in cold weather. There is a need for vehicle chargers during cold weather.

As for the raw data, the results were very positive. They include:

- All results automatically brought into a searchable database. No more paper to computer data entry errors
- No unreadable handwriting (except for problems with handwriting recognition software)
- Location easy to see in ArcPad when sending crews to make repairs (parcels, buildings, roads added to map)
- ArcPad mapping eliminates need for printed maps.
- Data quickly turned into shapefiles for inclusion on the DSM's ArcIMS web site.

As for the software we used. Everything worked as expected except for the limitations we encountered with Trimble's Mediamapper. The version of the program we used had a limited set of tools to satisfactorily present the data.

#### **Conclusion:**

The DSM has found Mobile GIS to be a genuine success. The biggest benefit, besides an increase in the quality of the data, was the speed in which data collection was accomplished. Benchmark results with the IT staff and a knowledgeable field staff member showed approximately 70 inspections were performed per day the first attempt, and that number increased to 90 inspections the next year due to familiarity with the equipment and procedure. Those inspections were not only performed in an 8-hour day, but crews also GPS'd the location, and took digital photos.

Once the raw data was accumulated, data was cleaned up and ready for analysis very quickly. Databases were immediately available, maps were made in a few days, and even Mediamapper produced a functional website a few days after data collection was finished.

Problems encountered were mostly training issues. We found the accuracy of the completed Manhole Inspection and Repair data was questionable because workers were not trained to accurately fill out the form.



Figure 5 – MediaMapper website

One of the things we noticed early on was the lack of understanding in filling out the Manhole Inspection or Manhole Repair form correctly. The IT staff was guilty of filling out incorrect forms. There needs to be an annual training session on data gathering techniques for these two forms to increase the quality of the data.

There were problems joining personal geodatabases to linked tables within the Geodatabase (check in/out data). We wanted to incorporate the new functionality of ArcGIS to check in/check out our data, but our current Geodatabase is constantly being revised and changed. If our GIS data sets were static, we would be able to use this new functionality.

We found Trimble's Mediamapper 3.1-20a to be a low end presentation tool for GIS data. The program we evaluated lacks adequate advanced presentation features. During the course of our study, MediaMapper was sold to Redhen Systems Inc. We have currently not evaluated the new version of the product.

Lastly, true "field editing" of our GIS data will need to be done by trained GIS/GPS Technicians. There is a steep learning curve to both develop and use Mobile GIS Technology. The existing field staff should not be expected to become a computer expert or programmer overnight, or after a little bit of training. Those that show interest

in the technology can be trained, but to expect a normal field worker to understand the complexities of shapefile editing inside ArcPad is not to be expected.

In conclusion, Mobile GIS is a great way to collect data and perform QA/QC of existing data in the field. However, there needs to be annual training to use the equipment, and training needs to be offered at every opportunity to get the field staff, and even the IT staff current with the technology. Also, there needs to be a factor of human/social engineering added to the project to motivate staff to use the new technology.

#### **Discussion:**

#### Human/Social Engineering:

The hardest part of rolling out Mobile GIS to a "technologically challenged" sewer inspection staff is overcoming the fear of the unknown and something new.

The existing field staff and staff in general have a big fear of the unknown. They do not like to change once they settle into a particular role or pattern. This isn't just a problem at the DSM, but it's an issue in other industries. How you react to this resistance will go a long way in deciding the success of your project.

What we are faced with in our workforce are field crews unwilling to adopt technology or recognize the benefits. This is partly due to lack of training, and their lack of knowledge on the subject. In general, there seems to be a divide in computer skills at the age of 40. Typically those workers under the age of 40 have a better understanding of this new digital climate our country and the world is moving towards. Those over 40, in general, have not grasped the new technology as quickly for whatever sociological reason.

Our challenge is training an aging field staff. The average age of a DSM's maintenance worker is 49 years old. In a system where the average retirement age is 55, a lot of these workers have retirement in their minds, and once you start thinking about retirement, you're already retired. To give a little background into the DSM, almost 75% of the entire workforce (~200 employees) eligible to retire in 10 years or less. Most of these workers have reached the maximum amount of vacation and accumulated time off. After field staff gets training; they aren't there to use the training. There is also a climate of abusing various loopholes in the system to take more time off.

So what you have is a typical worker that just wants to make it through the day, get his or her paycheck, and get out of there as quick as possible. There is an existing "Countdown to retirement" mentality. Why bother learning something new? Why bother working harder? "I get a paycheck no matter what". They have a comfortable way of doing things, and the unknown is scary, and creates tension.

In this existing job climate, how can you possibly get anybody to buy into Mobile GIS or any new technological change? In places with similar problems, money and pride in doing a good job don't seem to be a motivating tool. Successful project implementation requires a human engineering solution.

#### Keys for successful implementation:

Technology implementation is a social process. The hardest part of implementing a new technology is not concerns with operation or maintenance of specific details about project implementation, but with changing the behavioral patterns of existing employees.

Looking at the DSM, those districts where Mobile GIS is working have solid leadership. Strong leadership is the most effective solution to implementing any new technology.

Enthusiasm by your key project developers is another successful tool. The IT staff has fully embraced this new technology and the enthusiasm can sometimes be infectious once they show people what it can do.

Communication. Inconsistent rumors will develop in the startup of any project involving a change in the way things were done before. A good manager needs to communicate what is going on to all parties involved. For the Mobile GIS rollout to our field staff, we have made sure to give hands-on training, and to talk to each person involved in the project. There is a division Intranet that doesn't hide information, but freely distributes it. Surprises should be kept to a minimum in developing the project. Your end users can begin to trust you if you are honest with them, and can communicate effectively. Project managers should realize end users are their customers. Listen to them, and design with them in mind.

Managers need to show patience. A new project or cultural change in today's workforce needs time to be successful. Start simple in your goals, deliver functionality and increased goals in phases.

Training, Training, Training. To get over the fear of using the technology project managers need to be there to give end users support to show them how to overcome mistakes, and to operate the project correctly. Don't assume that one training session is enough. We've found the need to constantly train until staff are comfortable using the technology.

Make sure success is celebrated. Always reward those employees who have worked hard on a project to make it successful.

The most important item learned about implementing GIS projects to a "technologically challenged" staff is once it's there, people want more.

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