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GIS for Water/Wastewater

In This Issue

Mapping Capital Improvement Projects Improves Customer Service at Greater Cincinnati Water Works

By Lorraine Jordan, Senior Computer Programmer, and Keith Wempe, Senior Computer Programmer, GCWW

The Greater Cincinnati Water Works (GCWW), a utility that serves the City of Cincinnati, Hamilton County, and some neighboring municipalities in Ohio, launched an ArcIMS HTML viewer as an intranet site in August 2006. The site is devised to assist the engineering inspectors and customer service representatives in quickly finding information about GCWW's current capital improvement projects within the right-of-way. The application requirements were to develop an interface that was easy to access, carried no overhead on the desktop, and was intuitive to learn.

The Capital Improvement Projects viewer, also known as the CIP viewer, originated from an ESRI HTML template utilizing ArcIMS 9.1. The Web site runs on an Intel Pentium 4 machine used as a development server with Internet Information Server (IIS) and Apache Tomcat 5.0.

The template was customized by editing the existing JavaScript and HTML code to display tool links instead of buttons on the tool frame, a split table of contents frame that displays the table of contents and legend simultaneously, a quick zoom feature in the bottom frame, a help link in the top frame, and an automatic refresh of data layers in the map frame when the user checks on or off a visible layer. See figure 1.

At a glance, users can see any water-related CIP projects throughout the county. They can also zoom in to, quickly locate, and identify information from the graphic. The legend shows which projects are active and which projects are in their one-year warranty period. During the warranty period, the contractor is still responsible for repair and restoration. After one year from the closeout date, the graphic is automatically removed from the Web site.

Two of the most powerful features of the CIP viewer are the Find Address and Parcel Hyperlink tools.

The Find Address tool is an ASP.NET application that was developed as an easy way to find addresses within GCWW's service area and have the ability to zoom to the address with just a simple click. See figure 2. The core of this application is the geocode Web service developed by Cincinnati Area Geographic Information System (CAGIS). The Web service can consume a number of input parameters including addresses, intersections, expressway mile markers, state and U.S. routes, and important place-names such as police districts. The Web service will return an address if it falls within the range of addresses for that particular street whether it is an actual address or interpolated address.

After a search is made, the ASP.NET page returns a list of all possibilities. Each item in the list has an embedded hyperlink. The hyperlink passes a few parameters to the map, enabling it to zoom to the requested location

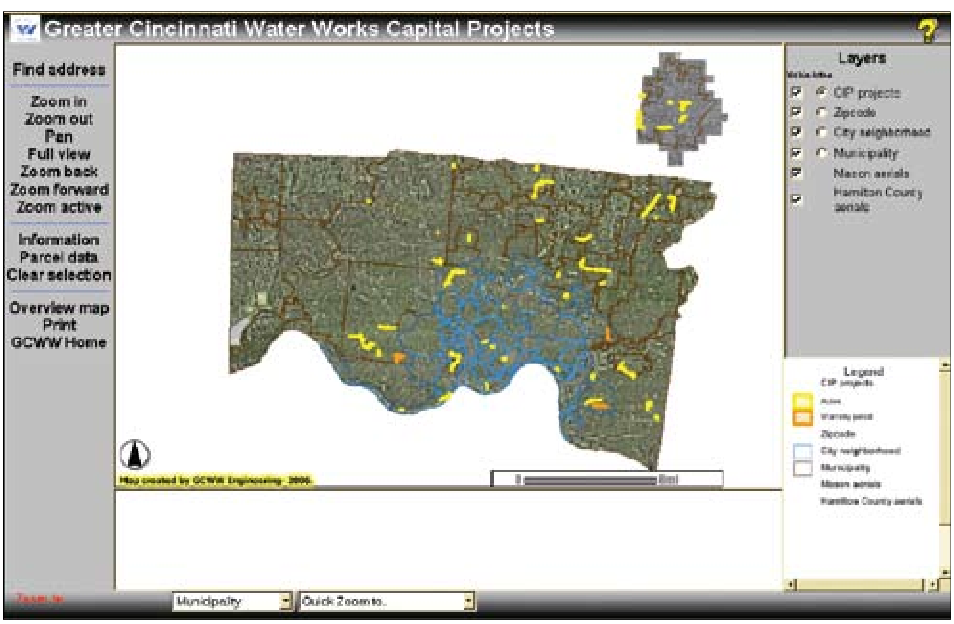

Figure 1. Online viewer shows capital improvement projects.

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Criticality-Based Fire Hydrant Preventive Maintenance Program

Will Allender, GISP, Asset Management Applications Lead, Colorado Springs Utilities

Colorado Springs Utilities, a four-service municipal utility serving Colorado Springs, Colorado, has approximately 21,000 fire hydrants within its water service territory. About 16,000 of these hydrants are publicly owned and maintained. Colorado Springs Utilities uses a 4,000' x 3,000' grid system to generate map book products for its field crews, and prior to 2006, these map grids were used as the basis for performing hydrant maintenance scheduling. Field crew personnel were assigned a map page and instructed to perform maintenance on every hydrant before moving on to the next page. This generally translated into performing maintenance along a north–south, east–west axis, regardless of the local neighborhood characteristics around each hydrant. This also limited work history tracking to the map page level, providing a range of dates for maintenance activities for a collection of hydrants, instead of a specific maintenance date for each individual hydrant.

Maintenance activities include the recording or verification of the depth of the valve nut; greasing the steamer cap threads; inspecting and replacing gaskets if needed; recording the hydrant static pressure; and verifying the paint color of the bonnet and steamer cap, which is determined by the modeled hydrant flow in gallons per minute.

In 2006, Colorado Springs Utilities set out to improve and optimize its preventive maintenance (PM) program, exercising and maintaining its most critical hydrants first. The Asset Management (ASM) group was called upon to perform the analysis of ranking the criticality of each hydrant and prioritizing the order in which hydrants would be visited for maintenance. This was accomplished using ESRI's ArcGIS 9.1, the enterprise geographic information system (GIS), and the ModelBuilder application within ArcGIS 9.1, which was used to create a systematic and repeatable analysis, while providing a graphic, documented workflow.

Project Team and Approach

To kick off the project, a team was assembled

that was made up of Colorado Springs Utilities' water stakeholders. This included internal representatives from the Asset Management group, engineers from Water Planning and Design, and planners/analysts and supervisors from Water Construction and System Maintenance. In addition, the Colorado Springs Deputy Fire Marshal participated on the team, providing both data and timely decisions to many of the analytical strategies.

The team met several times to identify data sources and methods for performing the analysis, which focused on establishing the criticality of each hydrant based on five different parameters. Once each parameter score was established, a composite score for each hydrant was calculated based on a weighted score for each of the five criteria. These five criteria included

- Proximity to wildfire mitigation zones
- Proximity to previously identified target hazards
- Land use
- Hydrant flow rates
- Spatial density of hydrants/Distance between hydrants

These criteria were used to kick off the project with the intent that they may become more refined over the life of the program. An overriding factor that permeated throughout all five criteria was the fact that the Colorado Springs Fire Department fights fires to save life first and property second.

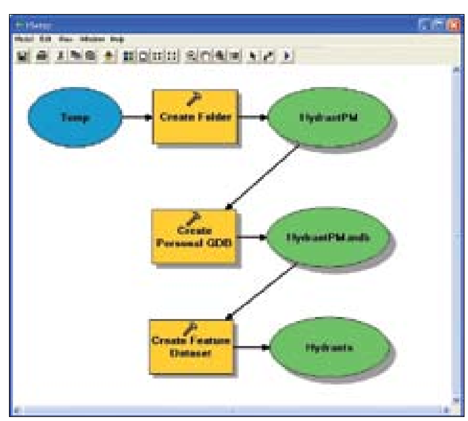
Anticipated results from the project included

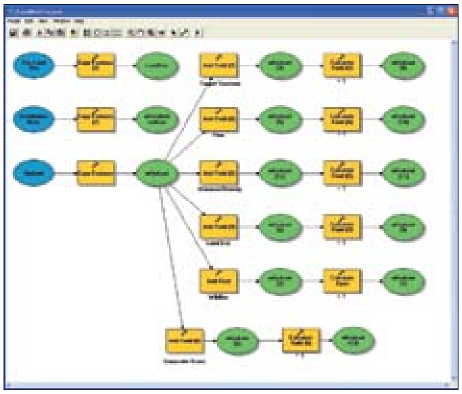
- A criticality ranking for every public hydrant for each of the five criteria
- A composite criticality score for every public hydrant
- A documented workflow for repeating the analysis as city growth occurred
- A statistical analysis of the results that would identify an effective blanketing of the entire city with a low-density subgroup of hydrants
- Research and a recommendation of GIS routing tools for efficient routing of field crews to visit each hydrant

To document the workflow of the analysis, as well as implement it in a repeatable script, Asset Management identified ESRI's ModelBuilder as the system of record for the analysis. The ModelBuilder model was designed to run the full analysis from start to finish with minimal interaction from the GIS analyst.

Initialization and Analysis

The first step in the model was to initialize the workspace and create a separate analysis personal geodatabase (PGDB). Many steps within the analysis generate temporal data for a specific point in time, and there was no business case for tracking the evolution of a hydrant's criticality as local characteristics change. Since Colorado Springs Utilities' enterprise GIS is in a tightly structured and versioned ArcSDE





geodatabase, it was decided to copy all necessary data out of ArcSDE and into a personal geodatabase when running the analysis.

Once the database was initialized, data was copied out of the enterprise GIS and into the working geodatabase. The dynamic data layers required for running this analysis included the fire hydrant point data, the water line feature class, and the city's land-use polygons. In addition, the PGDB hydrant feature class required new attributes for storing the criticality scores including the composite score. Each attribute was initialized to the lowest score of 1. During the course of the analyses, individual hydrant scores could be increased to 2 for medium criticality, or 3 for high criticality, for each of the five criteria.

In addition, several static datasets were stored in the initialization geodatabase, saved with the ArcMap .mxd and ArcToolbox .tbx files for the project. Datasets include the Wildfire Mitigation Zone polygons; point features for critical addresses identified by the fire department; and a land-use lookup table, which has a criticality score assigned to each type of land use.

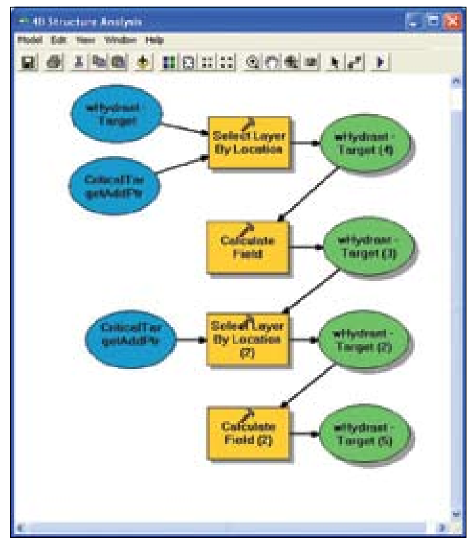
Criteria 1: Wildfire Mitigation Zones

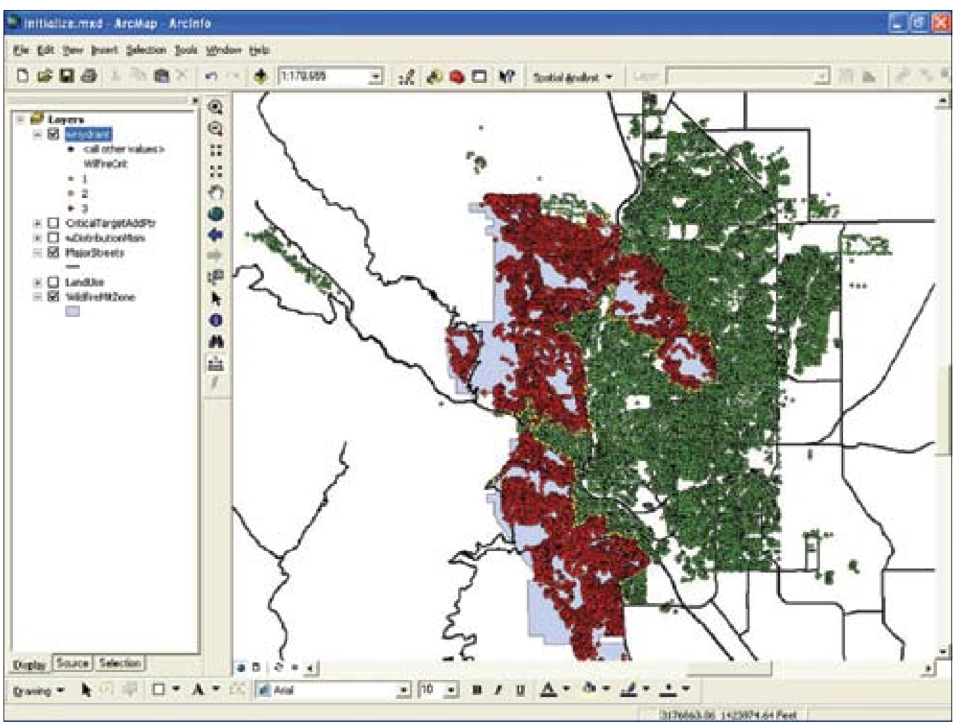
The Colorado Springs Fire Department maintains a polygon dataset called the Wildfire Mitigation Zone. This zone provides a buffer between the downtown urban areas of Colorado Springs and the toe of the slope going up to Pikes Peak as well as to several adjacent mountains. This zone is especially critical with regard to fire prevention. Once a fire starts up the side of a mountain, it rapidly burns out of control and this could have dramatic effects to Colorado Springs, whose water supply is stored in nearby mountain reservoirs.

Fire hydrants located within the mitigation zone were ranked with a score of 3; hydrants within 500 feet of the zone scored a 2; and all other fire hydrants retained their initialized score of 1, for the proximity to wildfire mitigation zone criterion. The use of the 500-foot length for breakpoints is a fire department standard and is based on hose lengths. Scoring and attribute calculation were performed using a standard Select By Location query and the Calculate Field tools found within ArcMap and were scripted within ModelBuilder.

Criteria 2: Analyze Target Hazards

The Colorado Springs Fire Department Office of the Fire Marshal (OFM) maintains a list of approximately 400 addresses of locations or structures that are deemed critical. These locations generally include hospitals, schools, churches, sports facilities, municipal buildings, and specific high-density apartment complexes. These addresses were geocoded and used to create a static point feature class stored in the initialization PGDB.





The image above shows the scoring of individual hydrants for the proximity to wildfire mitigation zone criteria, where red indicates highly critical (score = 3) hydrants, yellow represents medium criticality, and green represents low or least critical. Pikes Peak is located west of downtown Colorado Springs, so the pattern shown above was highly predictable, forming a western barrier between the city and the mountains.

For criticality ranking, hydrants within 1,000 feet of the address points received a score of 2. A reselect was then performed, scoring hydrants within 500 feet of the addresses with a score of 3. All other hydrants retained their initial score of 1.

Criteria 3: Analyze Land Use

The City of Colorado Springs maintains a polygon LandUse GIS layer. The LandUse codes and descriptions were reviewed by the stakeholder team members, and a criticality score was assigned to each land-use type. Generally, high-criticality land uses include high-density residential, office, commercial, industrial,

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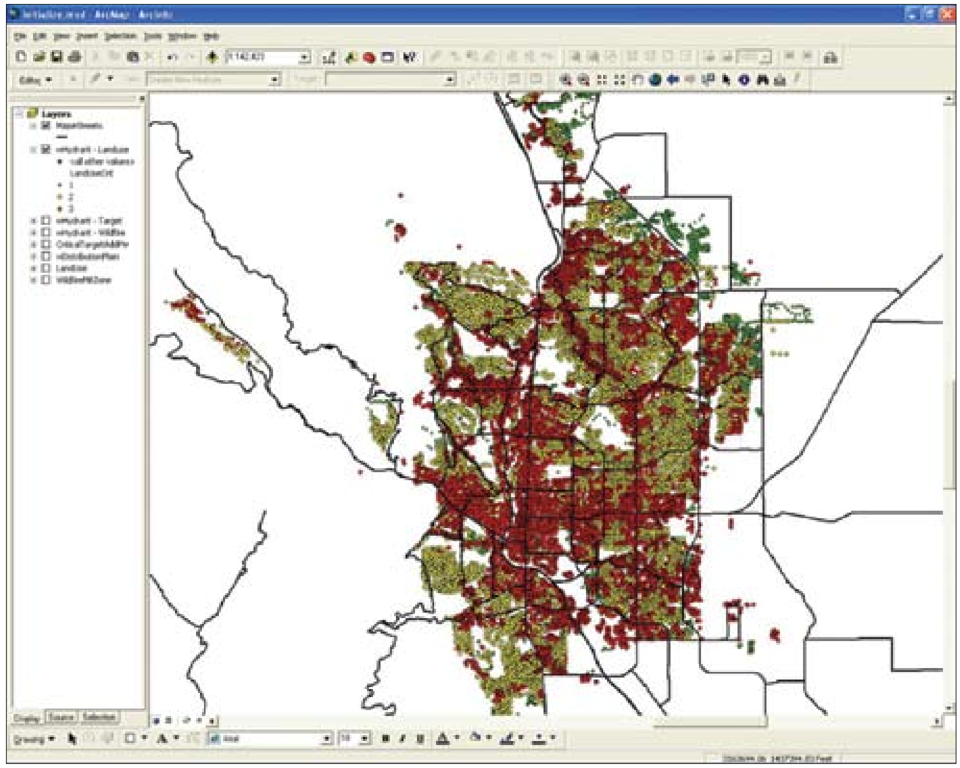
Criticality-Based Fire Hydrant Preventive Maintenance Program

institutional, educational, municipal, and other public assembly locations such as sports arenas. Medium-criticality land uses include lower-density residential. Low-criticality land uses include parks, open spaces, golf courses, street rights-of-way, parking lots, and vacant land. Criticality scores were assigned by stakeholders and stored in the LandUse lookup table in the initialization PGDB.

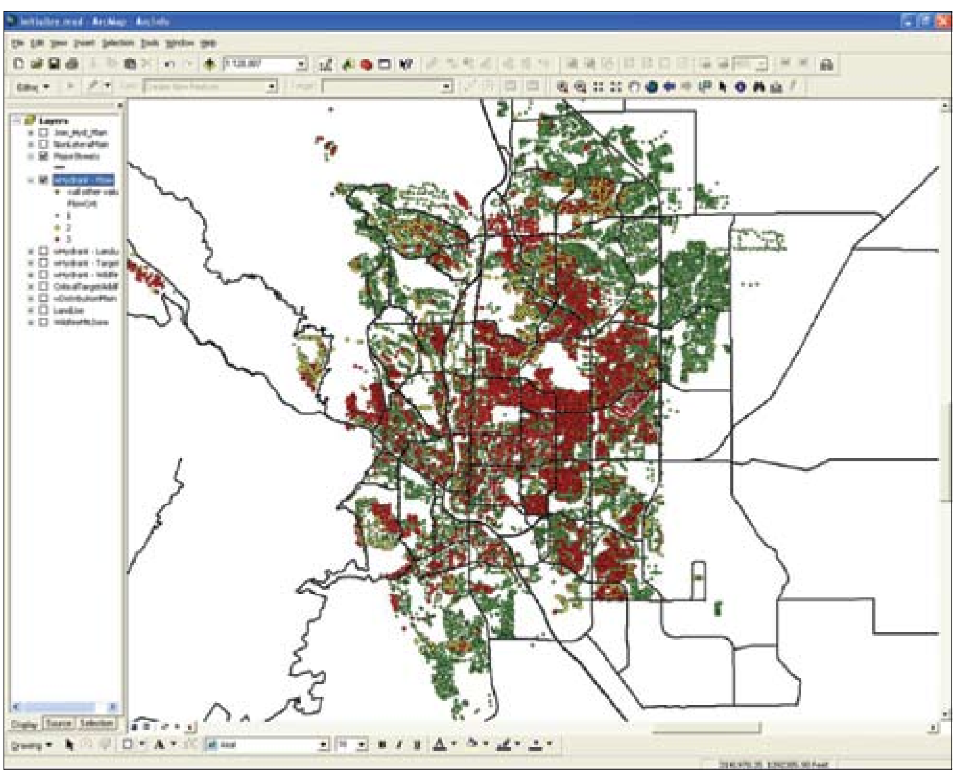
LandUse polygons were buffered by 200 feet to eliminate slivers in the data, particularly along right-of-way corridors, where most hydrants are located. Medium-criticality land uses were scored first, followed by high criticality second, allowing scores to be trumped by higher-criticality land uses in close proximity.



In the image above, there is a prevalence of red, high-criticality hydrants in the city core area and along major highway arterials and intersections. Yellow, or medium-criticality, hydrants make up the bulk of the remainder areas, and green, low-criticality hydrants can be found in the lowest-density perimeter areas.

Criteria 4: Analyze Flow Rate

Hydrant flow rates are modeled on a case-by-case basis by Colorado Springs Utilities' Planning and Engineering Department. However, currently the GIS does not store flow rates due to its dynamic nature. To perform this analysis, flow rates were derived empirically, based on the pipe size of the nearest water main, excluding hydrant laterals. All hydrants whose nearest pipe was eight inches and greater or with a PVC pipe six inches and greater were ranked low criticality because they were generally considered to have a relatively high flow. Eight-inch ductile iron pipes were ranked medium criticality. All hydrants whose nearest pipe was less than eight-inch or had a PVC pipe less than six inches were ranked high criticality, or 3, due to their relatively low flow.



This image shows the results of the flow rate analysis within ArcMap. The patterns shown in this screen capture are indicative of many existing four-inch water mains in the older parts of the city, on the northeast side of the downtown core.

A spatial join was a primary component of this analysis step. In ArcGIS 9.1, spatial joins could not be performed within ModelBuilder. However, this functionality has been exposed in ArcGIS 9.2, and the models are in the process of being updated.

Criteria 5: Analyze Hydrant Density

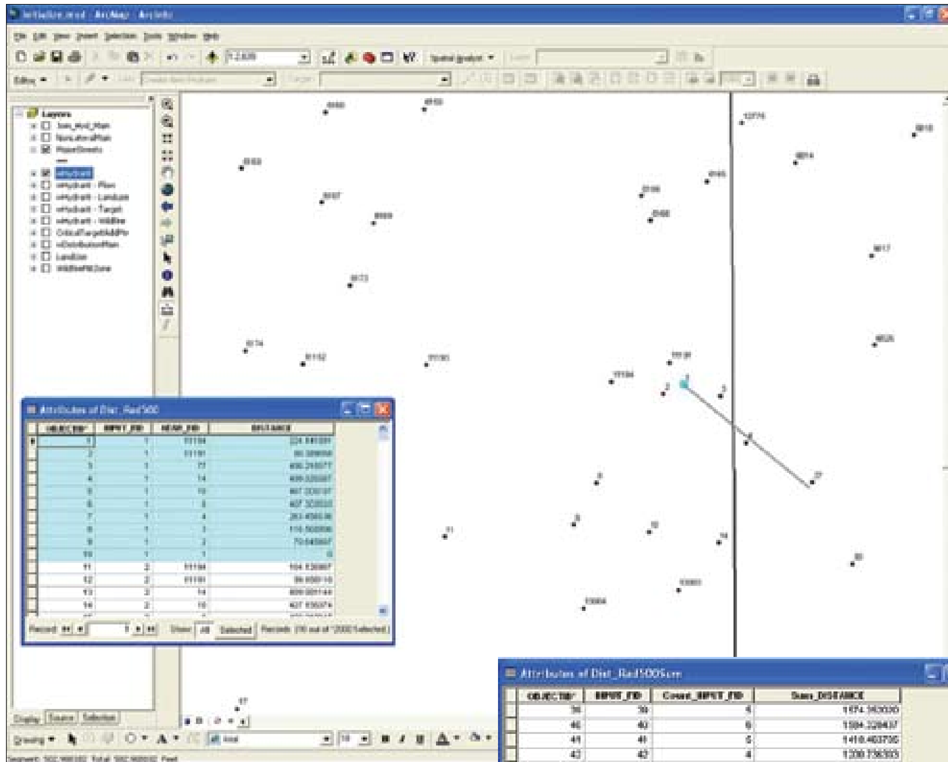
Colorado Springs Utilities maintains survey-grade GPS locations for all hydrants in the water system, both public and private. A distance/density analysis was performed on the hydrant point features, ranking them as high, medium, or low criticality based on the following rubric:

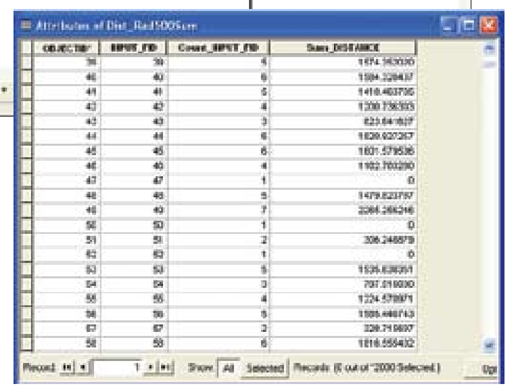
- Public hydrants within 500 feet of one another were ranked low.
- Public hydrants greater than 500 feet from another public hydrant, but within 500 feet of a private hydrant, were ranked medium.

- Public hydrants not within 500 feet of any other hydrant were ranked high.
- Private hydrants were not specifically ranked because they are not maintained by Colorado Springs Utilities.

The rationale used was based on the idea that hydrants in remote locations were more critical because there was no nearby hydrant to use as a backup if the hydrant failed to deliver water. Preferential ranking was also given to public hydrants within 500 feet because they have a better history of producing water compared to private hydrants, which receive little or no maintenance.

The first step in the distance analysis involved running the Point Distance tool, available within ArcToolbox, using a 500-foot search radius. The output from this step was a table listing a separate record for each point, to each other point within the same feature class, within 500 feet. If no other points were found within 500 feet, a single record was created with a distance of zero. In the image shown above right, point FID 1 has 10 point features within its search radius, highlighted in the table. A 500-foot measure line is also shown.





Next, the table was summarized on the INPUT_FID field with a Sum statistic included for the DISTANCE field. This resulted in a new table with one record for each INPUT_FID. At this point, every record in the table whose Sum_DISTANCE was equal to zero was queried and identified as having no other hydrant within 500 feet. The results of this query were joined back to the original hydrant feature class, and those hydrants were calculated to a criticality of 3, for high criticality. Since all hydrants were initialized with a score of 1 for this criterion, all that was left to determine was which hydrants needed a score of 2.

To accomplish this, the hydrant feature class was queried to determine which hydrants were owned and maintained by Colorado Springs Utilities. The Point Distance tool was then rerun, using a 500-foot search radius. Once again, this table was summarized on the INPUT_FID field with a Sum calculated on the DISTANCE field. Zero sums were queried and joined back to the hydrant feature class. This selection set represented public hydrants that were not within 500 feet of each other. Many of these were already scored as 1 or 3, from the initialization process or the previous step. By eliminating those hydrants whose score was already set to 3, the remaining hydrants were calculated to 2, for medium criticality.

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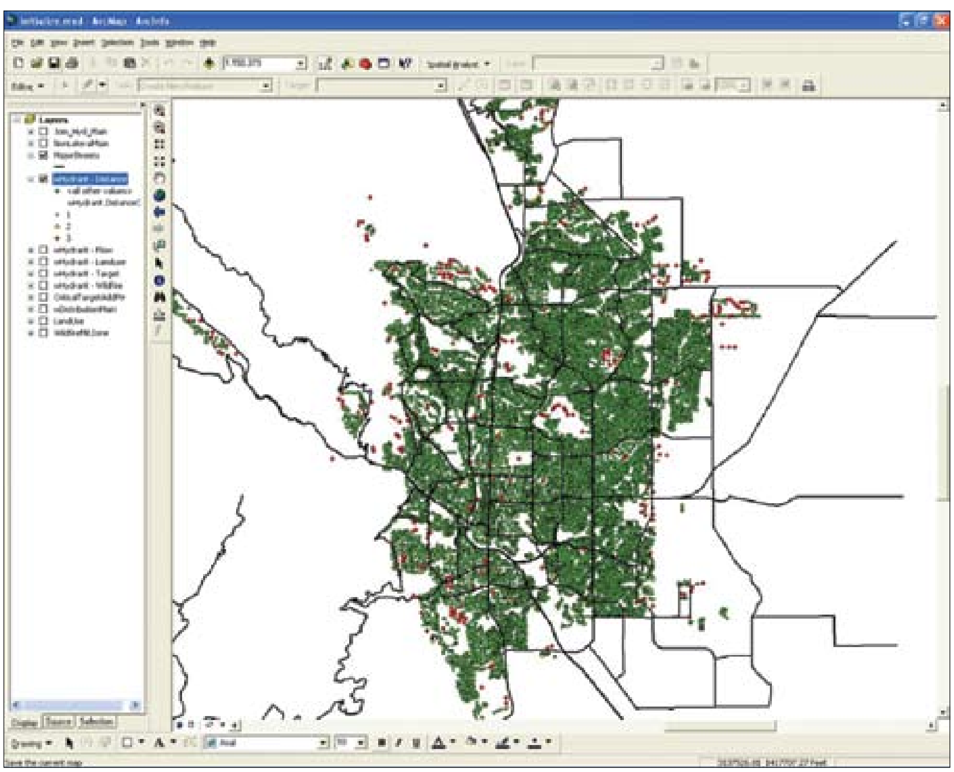

The final results of the distance analysis are shown above.

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Composite Score

Once all five criteria were scored for each hydrant, it was time to synthesize the data into a composite score. Conceptually, this process is very similar to map algebra. Each of the five values must be weighted and either added or multiplied together. After much discussion among the team stakeholders, it was decided that some criteria behave like "opportunity" constraints and should be added to the total, while other criteria behave like "severity" constraints and should therefore be multiplied into the total. For example, a fire cannot suddenly become more severe by having an administrative boundary such as a land-use change. However, it can become more severe if the water pressure doesn't support adequate fighting of the fire or if a few extra minutes are required to lay hose to the next nearest hydrant. For this reason, flow rate and hydrant distance became multiplicative constraints while land use, wildfire mitigation zone, and target hazards became additive constraints.

Composite scores were calculated and the resulting histogram was analyzed, looking for data outliers that could represent the critical hydrants. Using the Jenks' Natural Breaks classification scheme, 16,681 public hydrants were classified into three distinct groups:

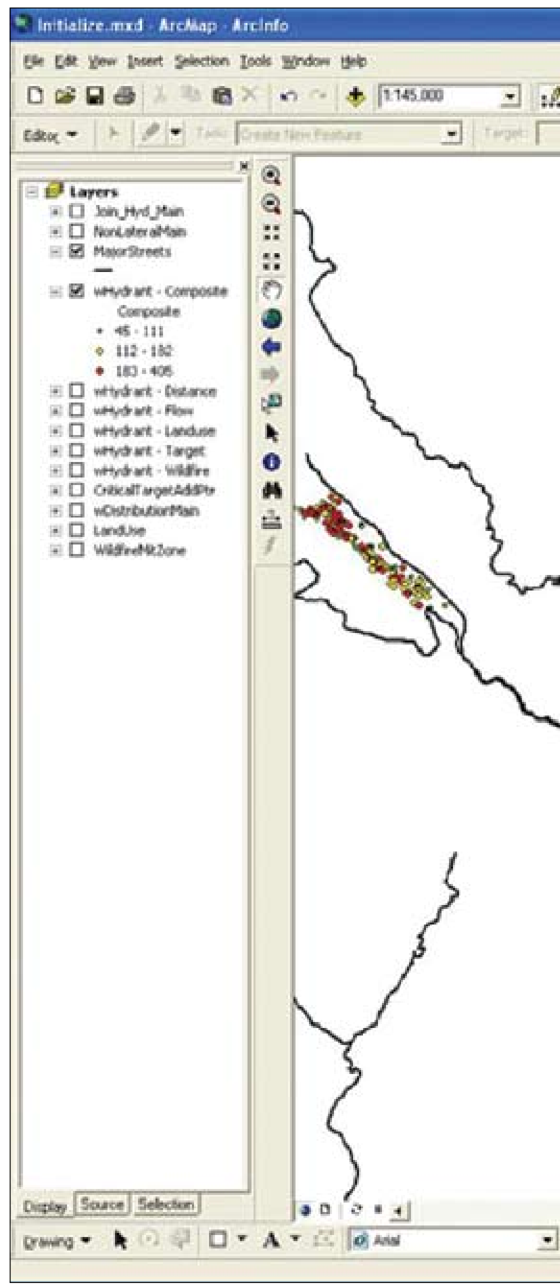
- 10,625 low-criticality hydrants
- 3,475 medium-criticality hydrants
- 2,581 high-criticality hydrants

Routing of Maintenance Activities

The final step of this initial hydrant PM kickoff project involved building routes for field crews for visitation of hydrants to perform maintenance. The maintenance crew supervisors reviewed the criticality patterns in the composite map, knowing that the highest-criticality hydrants would be visited first. However, it was determined that there were too many cases where a crew would be driving past several hydrants to get to the one to be worked on. The supervisors thought this would cause too much confusion among the field crews.

Thinking about the visual and psychological aspects of driving the route in the field, it was decided to include all hydrants within 250 feet of the high-criticality hydrants in the initial routing exercise. This translated into a final result of approximately 3,200 hydrants in the initial route set, composed of both the high-criticality hydrants and the spatially routable hydrants.

Since Colorado Springs Utilities did not previously have a routing application, these first 3,200 hydrants were manually routed, by plotting out a poster of the results and deter-



mining how to best drive the route, with the goal of visiting 25 hydrants per day, per crew. This entire manual routing effort consumed 80 hours of analyst time to route the 3,200 hydrants. This set the stage for a business case for obtaining a better routing solution, knowing that another 13,600 hydrants would need to be routed for preventive maintenance, with a possible follow-up routing case for a separate hydrant painting program.

Several routing applications were pilot tested including ESRI's ArcGIS Network Analyst and ArcLogistics Route and RouteSmart's high-density routing application. RouteSmart has been an industry leader for routing utility meter readers for years, and this turned out to be the best solution. With minimal training, analysts repeatedly created routes for field crews to visit the remaining 13,600 hydrants, using several different factors for load and time balancing, all performed in a matter of hours. Colorado Springs Utilities is also now finding many other business uses for RouteSmart in its operations and maintenance (O&M) activities.

Summary

This project emphasizes the use of ArcGIS technology within the Asset Management program at Colorado Springs Utilities. According to David Totman, supervisor of the ASM Systems Planning Unit, "Our GIS inventory has moved beyond mapping and is now supporting business processes through analytical tools, such as the hydrant criticality ModelBuilder model, and streamlining our workflow efforts through routing logistics of O&M activities." Being a four-service utility responding to the dynamics of a growing city, having easy-to-use tools such as ModelBuilder is critical to providing adaptive solutions as the elements of criticality can, and do, change. The acceptance and success of the model are due to the collaborative nature in which the project was developed. Having input from both utility and city personnel was crucial in delivering an effective and sustainable tool.

Contacts for Information

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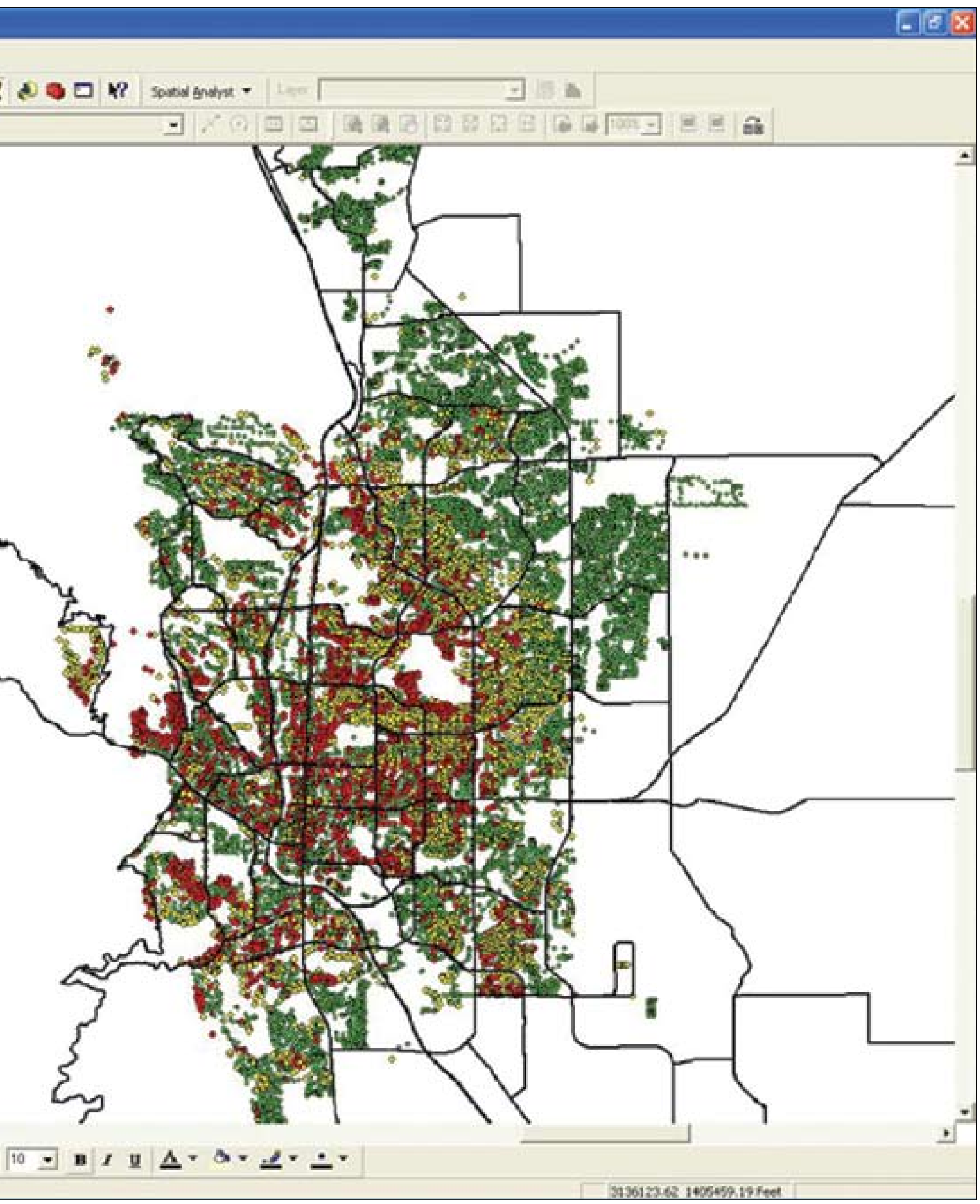

This image represents the final composite scoring for 16,681 fire hydrants. Red points are high criticality, yellow are medium, and green are low. The overall patterns seen by the point distribution visually support the concept of an "effective" low-density blanketing of the city, with regard to hydrant preventive maintenance.

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and place a label with the selected information. This functionality makes it easy for nontechnical users to perform searches, zoom to locations, and get information from the map.

The second feature is the Parcel Hyperlink tool. This tool opens the Hamilton County auditor's tax assessment records Web site when a user clicks on a parcel in the map frame. Customer service representatives utilize this on a daily basis to see if a parcel has changed ownership. See figure 3.

The capital improvement projects are displayed in the form of a shapefile (.shp) within the ArcIMS viewer. The information in the shapefile is generated by a custom .NET application connected to a personal geodatabase. This custom editor was tailored to the specific

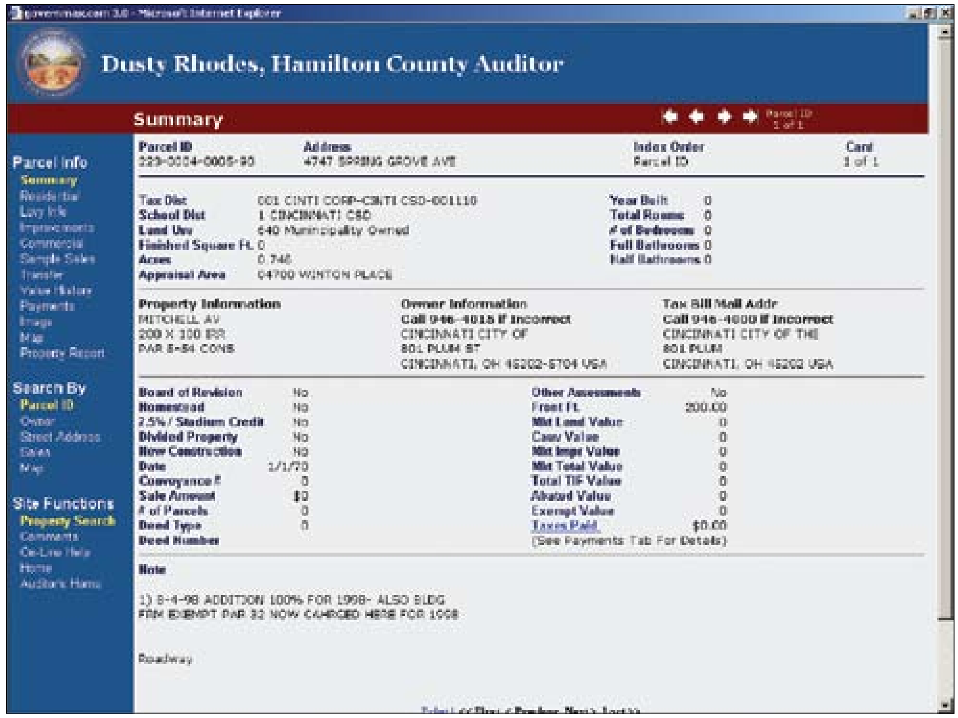

Figure 3

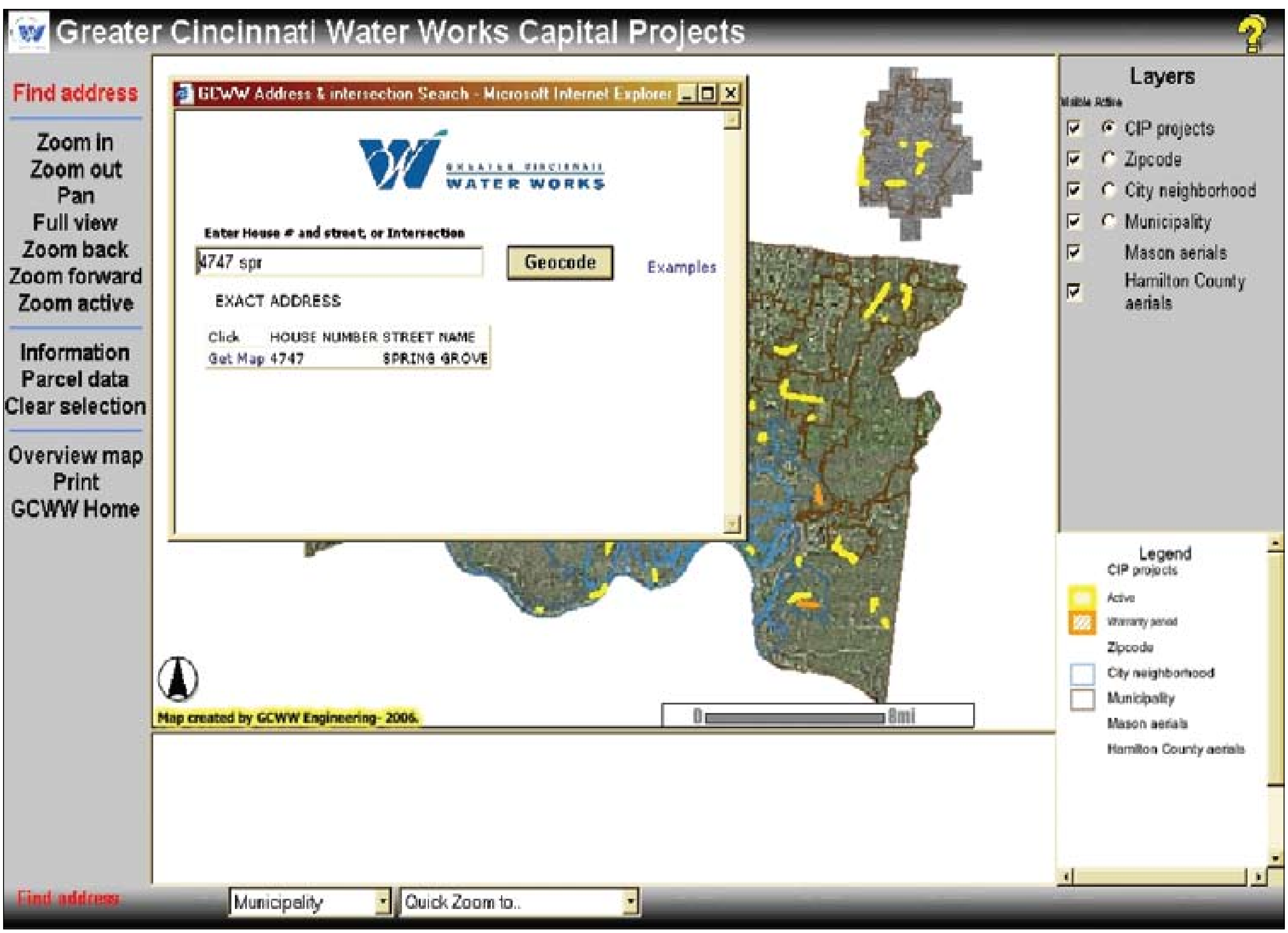

Figure 2

task of creating and editing features for the CIP viewer. See figure 4.

The editor application uses the same geocode Web service for zooming to locations by address or intersections. This application makes it possible for someone with little to no GIS experience to create these features.

The first step is to create a project area polygon. Once the polygon is created, attributes are automatically added through just a couple of clicks, eliminating manual data entry. Attribute information is loaded from a semicolon delimited text file. The text file is created by a job service run nightly from GCWW's Primavera project management software. The text file contains information on all current and active capital projects.

However, the user is not bogged down with sorting through all projects. Instead, the CIP editor filters projects in the text file against the projects already entered into the geodatabase and makes available only projects that do not have a corresponding polygon.

The status of a project is very important to the engineering inspectors. Once the project is complete, the status changes from Active to Warranty. The legend shows active projects in yellow and warranty projects in orange. After one year, the status automatically changes to Completed and is dropped from the viewer.

Through this streamlined process, GCWW is able to make available timely information pertaining to all the capital improvement projects that is easily accessible and up to date. These tools enable customer service representatives to answer questions about projects without a delay in response to customers.

Trade Shows

APWA 2007
September 9–11
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AMR Autovation 2007
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WEFTEC 2007
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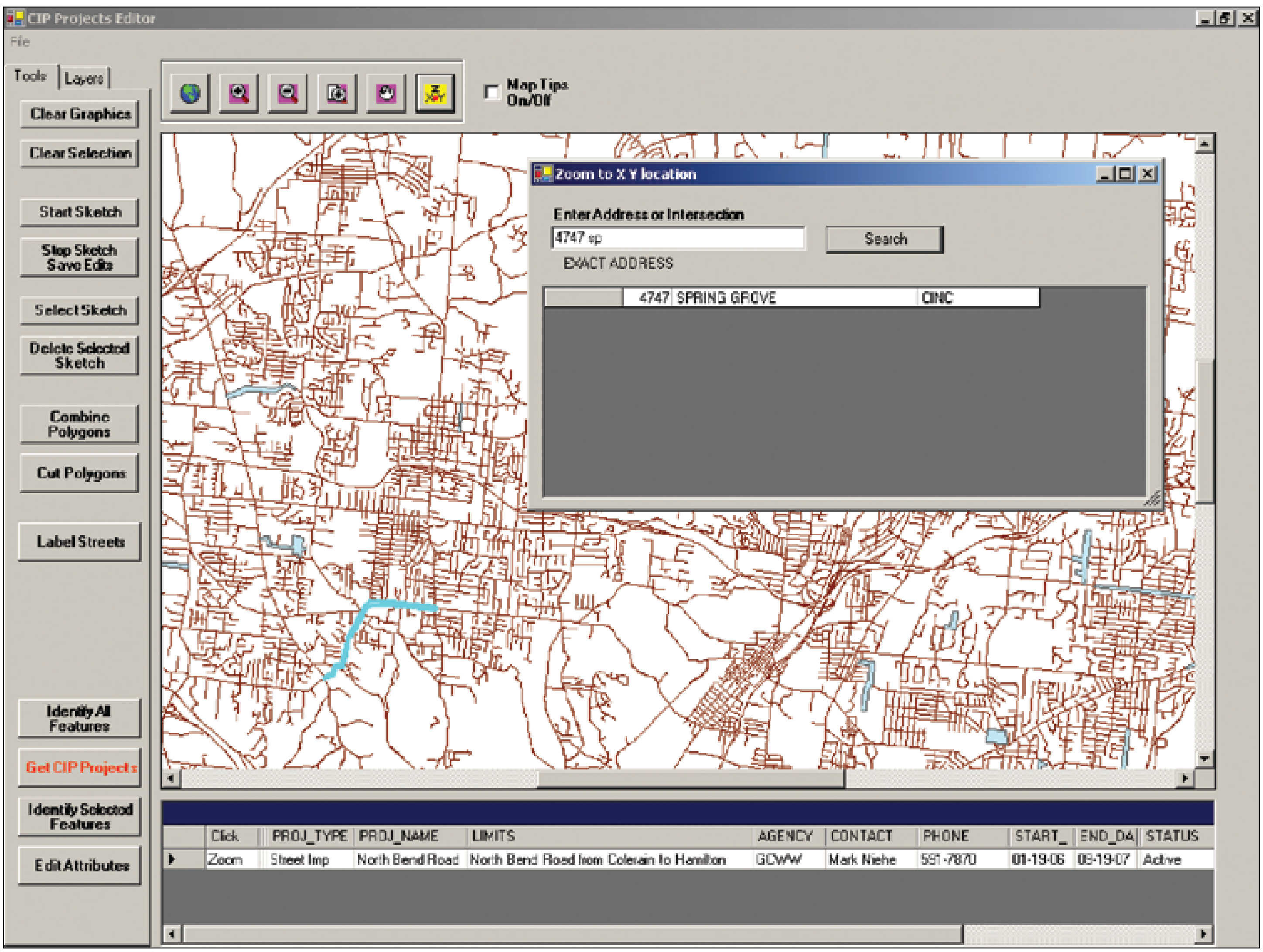

Figure 4

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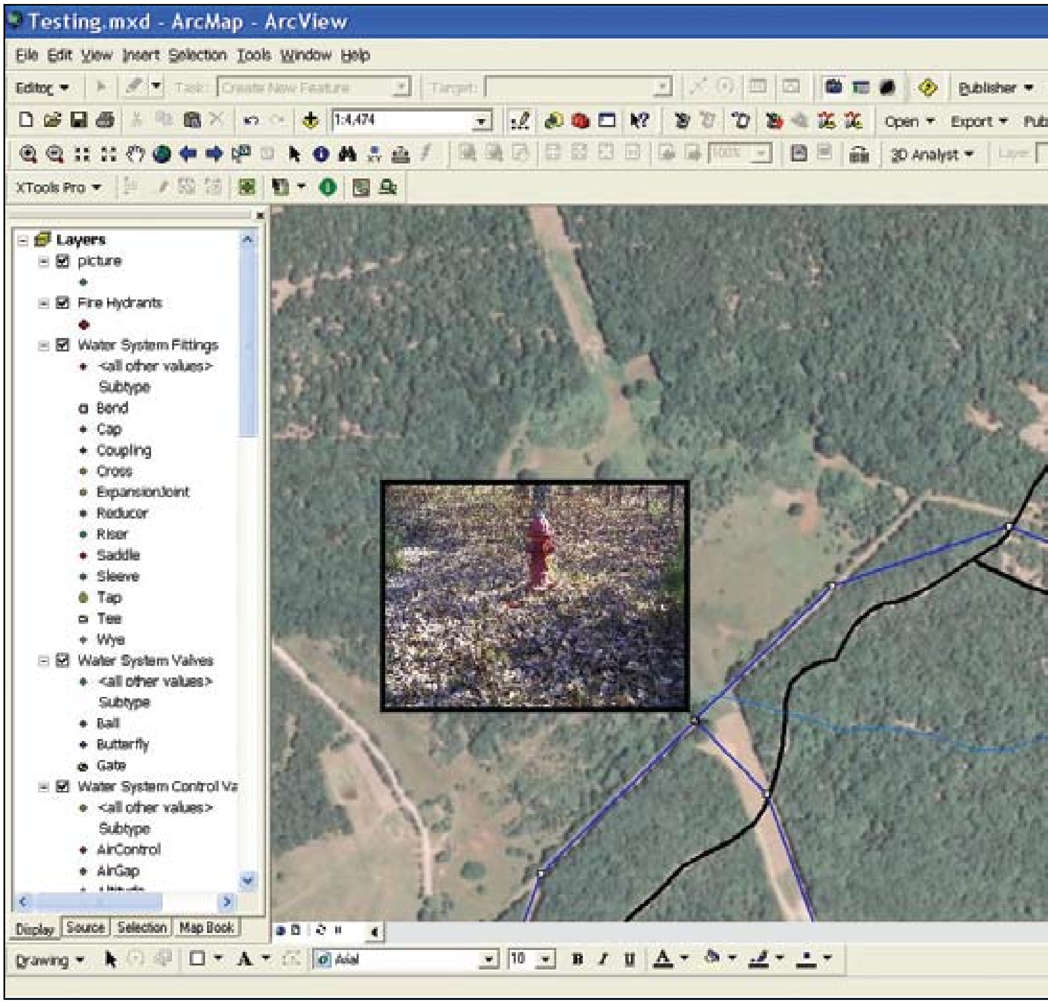
Wind Environmental Services, LLC, is one of the premier providers of GIS solutions to the water and wastewater industries. Having on staff professionals licensed in several states in both water and wastewater treatment, distribution, and collections as well as ESRI Authorized Instructors gives Wind Environmental a unique firsthand perspective when assisting clients.

In addition to being an ESRI Authorized Business Partner and Value-Added Reseller, Wind Environmental is a business partner/reseller with Magellan Navigation, Juniper Systems, LizardTech, LaserCraft, Ricoh, and GeoSpatial Experts. A unique blend of products from these organizations coupled with Wind Environmental's training and support allows the company to provide a variety of GIS solutions to the water and wastewater industry.

One of the specialties of Wind Environmental is its flexibility when creating mobile GIS solutions. The company can truly tailor a system to the exact needs of the project, whether it's a basic GPS system using ArcPad or an advanced configuration requiring laser offsetting and a customized ArcPad interface. By having water and wastewater industry professionals on staff, Wind Environmental can not only tailor the overall system but also its training to accommodate end users' exact needs.

All the GIS systems implemented by Wind Environmental are built on the ESRI suite of



Water distribution system map displays photos of fire hydrants within the ArcMap interface.
Inset: ArcPad map displays water meter locations.

products including ArcView, ArcPad, and ArcIMS. Systems range from single-user environments using a personal geodatabase to multiuser versioned environments using ArcSDE. Wind Environmental is known for leveraging the software to support industry-specific tasks such as managing both sample site locations and sample results, allowing the user to take advantage of the reporting and graphing capabilities as well as the mapping functions of the software. Mobile tasks that have field personnel collect locations and attributes of water main breaks and system blockages allow utilities to archive data to not only visualize where they need to perform system upgrades using ArcMap but also generate reports detailing the amount of hours spent and cost of materials that were used repairing the damaged area. Linking photos of inspections, meters, valves, and manholes to points or features inside ArcMap assists in the recovery of damaged or buried features in the field.

To learn more about Wind Environmental Services, LLC, and how the company can assist with your GIS and mapping needs, contact

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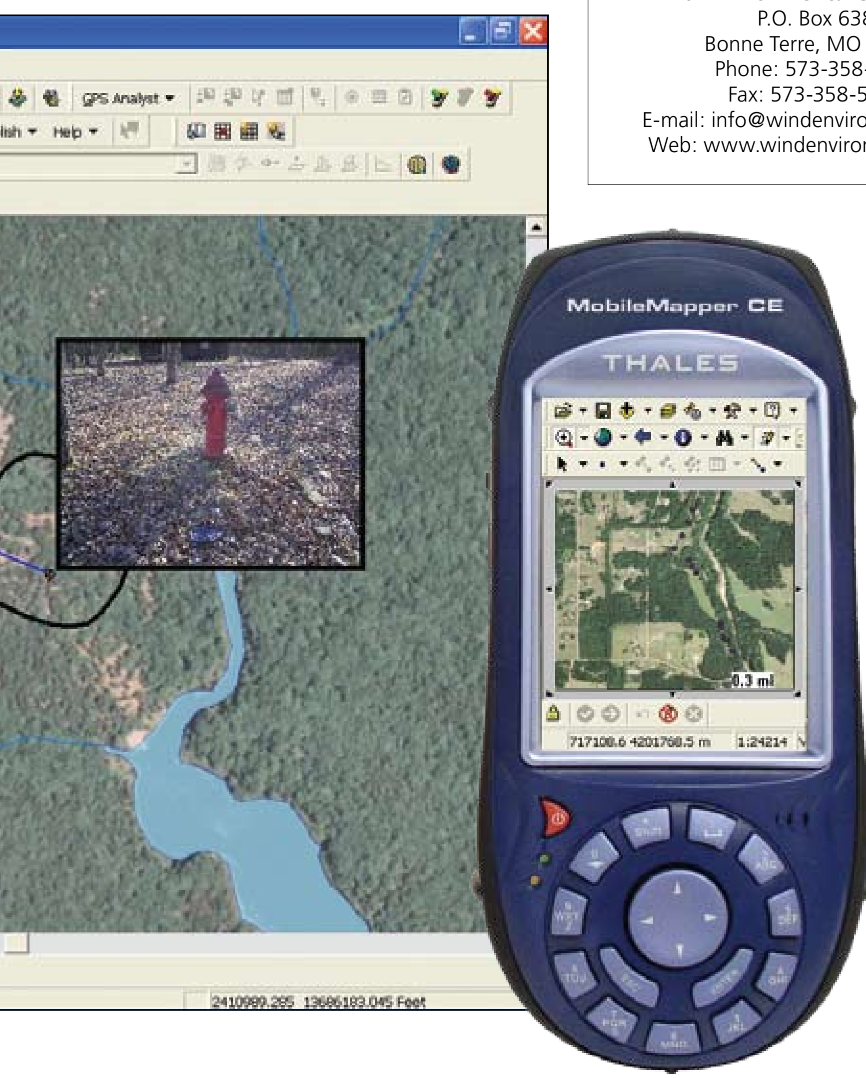

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