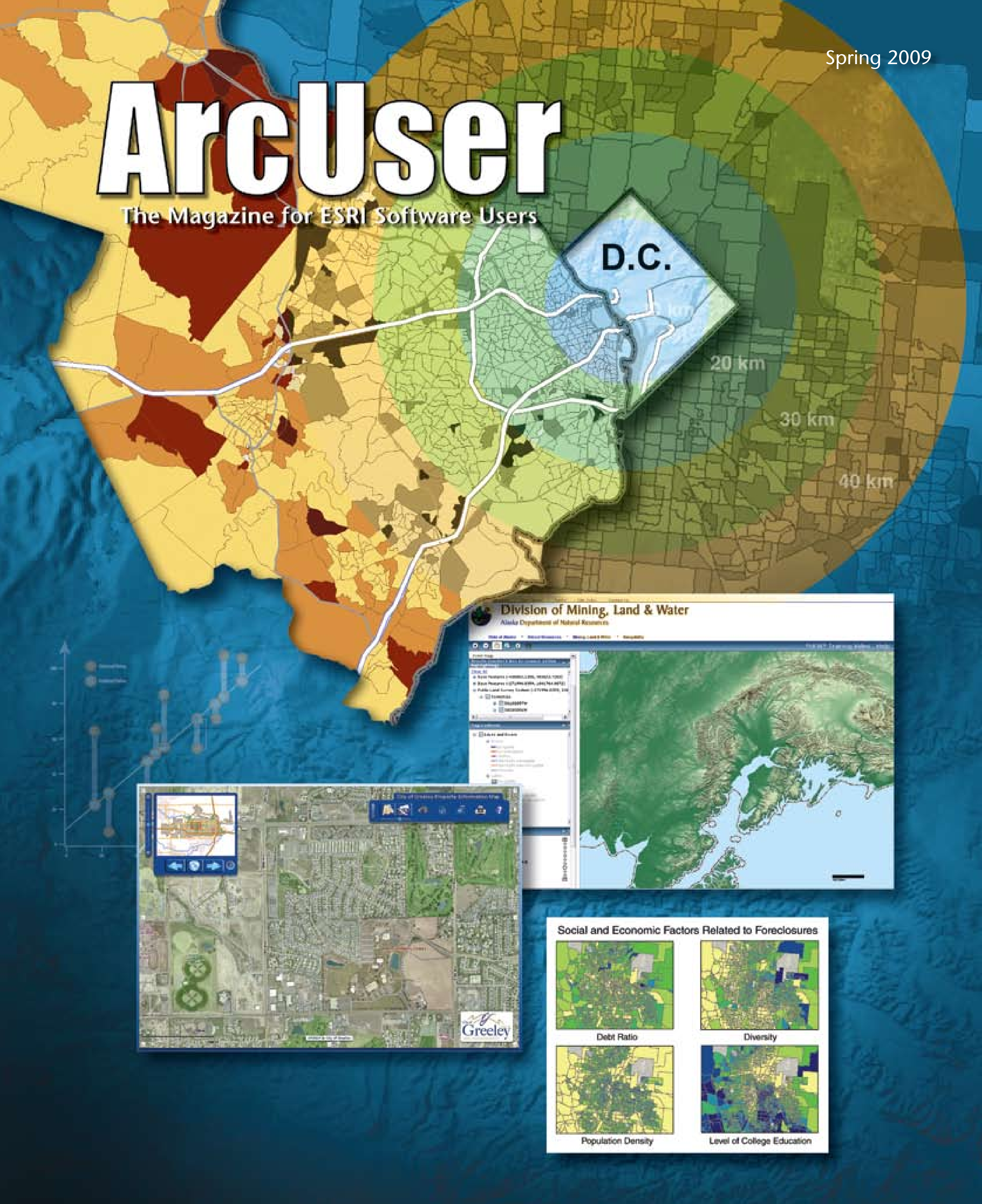
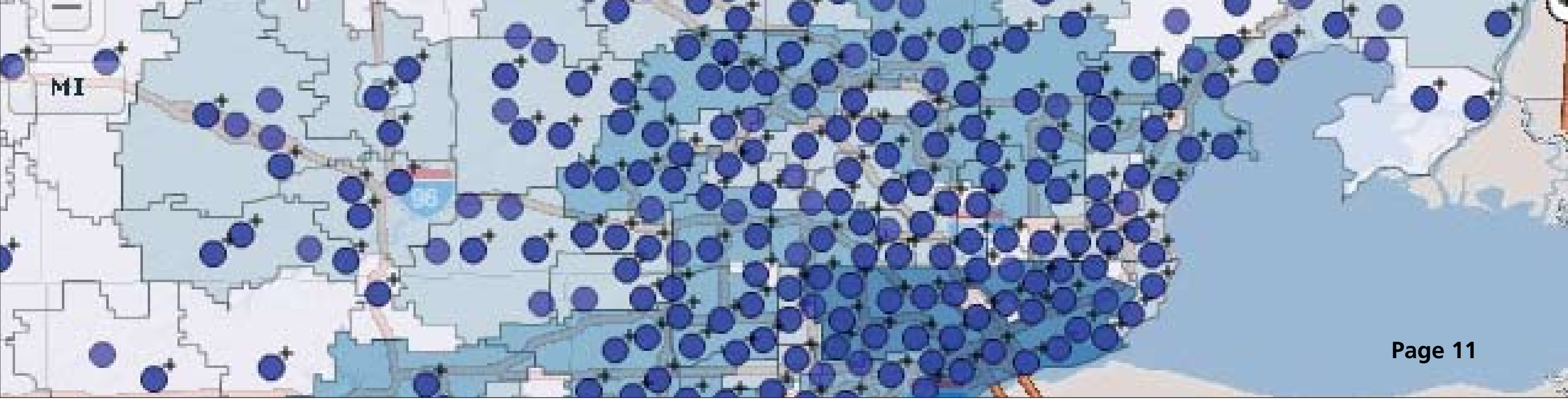
Spring 2009

# ArcUser

The Magazine for ESRI Software Users




## Building Geospatial Infrastructure




Spring 2009 • Vol. 12  No. 2

# FOCUS

**16 The Next Step**
The importance of building geospatial infrastructures

**18 A Geospatial Foundation**
Public, private, and military applications flow from SDI

**22 Improving Regional Water Quality Assessment**
Geodatabase improves data management and analysis capabilities

# FEATURES

**24 It's All about Context**
Remapping mammoth bone bed with ArcGIS

**28 Modeling Small Areas Is a Big Challenge**
Using the solar radiation analysis tools in ArcGIS Spatial Analyst

# SPECIAL SECTION

**40 Answering *Why* Questions**
An introduction to using regression analysis with spatial data

**40 Regression Analysis Components**
Terms and basic concepts

**44 Applying Geographically Weighted Regression to a Real Estate Problem**
An example from Marquette, Michigan

115206
QUAD382M3/09tj

# Transformation and Innovation

## Converting data to information using GIS

The digital universe of the Internet has grown larger and faster than anyone could have imagined 16 years ago. According to *The Diverse and Exploding Digital Universe,* an IDC white paper sponsored by EMC Corporation and published in March 2008, the Internet encompassed 281 exabytes (or 281 billion gigabytes) of data in 2007. In that year, all the data created, captured, or replicated exceeded the space available to store it. Although not all data created and transmitted is saved, this report predicts that by 2011 almost half the digital data on the Internet will lack a permanent address.

Like Samuel Coleridge's ancient mariner who exclaimed, "Water, water, every where, Nor any drop to drink," the world appears to be heading for a future awash in data but thirsting for actionable information on topics vital to the well-being of society and the planet.

GIS has emerged as a framework for channeling this tidal wave of data and transforming it into information that can be applied to a wide range of problems.

Recent developments in both GIS software and strategies for geospatial data management are helping organizations use the geographic approach to accomplish goals more effectively. As articles in this issue illustrate, this is true whether those goals are responding to fires more quickly or optimally siting wells that provide safe drinking water.

New regression analysis tools in ArcGIS 9.3 for modeling and exploring data provide ways to better understand and use data. The Special Section highlights the new Ordinary Least Squares (OLS) Regression and Geographically Weighted Regression (GWR) tools now available in ArcToolbox. These tools go beyond answering *where* questions to explore the reasons *why* things happen.

GIS tools not only help uncover the structure of data to answer specific questions but, combined with utilities and scripts, can be used to compile data originally gathered for a variety of reasons and generate new information. The aggregated live feeds methodology, described in an article in the Developer's Corner, is an example of the power of assembling data in a geospatial framework. Using this technique, constantly updated monitoring and measurement data from many sources is combined to furnish information in near real time.

The intelligent use of data, whether modeled or compiled, depends on knowing its accuracy, currency, and ownership. However, creating and maintaining standards-based metadata is an oft neglected task. An article in the Hands On section suggests simple changes that can streamline the metadata production workflow while enhancing the quality of the final product.

Metadata, along with standard geographic datasets, workflows for updating these datasets, and focused applications, is the foundation for building a geospatial infrastructure that can improve the operations of existing industries and help create new ones. The Focus section of this issue includes articles that describe the process and benefits of creating geospatial infrastructure at both the regional and national levels. Each organization has taken an abundance of diverse data; organized it geospatially; and developed applications, processes, and products that allow it to weigh options, get answers, and solve problems.

Monica Pratt

Monica Pratt
*ArcUser* Editor

# editor's page

**ArcUser**
The Magazine for ESRI Software Users

Spring 2009 • Vol. 12 No. 2



**HOW TO REACH US**
Visit the *ArcUser Online* Web site (**www.esri.com/arcuser**) to download tutorials, read current and past issues, and access additional resources.

For all subscription, advertising, or editorial inquiries, call 909-793-2853, ext. 1-2730.

***Your* ArcUser *Subscription***
To subscribe, unsubscribe, or change mailing information online, please go to gis.esri.com/emails/arcuser_subscr.cfm or send e-mail to arcuser_circulation@esri.com.

***Advertise in* ArcUser**
For information regarding placing an advertisement in *ArcUser* magazine, contact the advertising coordinator at 909-793-2853, ext. 1-2189 or ads@esri.com
Fax: 909-307-3051

***Editorial Inquiries***
Monica Pratt, *ArcUser* Editor
380 New York Street
Redlands, CA 92373-8100, USA
E-mail: arcuser_editor@esri.com
Visit the *ArcUser Online* Web pages (**www.esri.com/arcuser**) to read the article submission guidelines and copyright policy.

ISSN 1534-5467
*ArcUser* is published quarterly by ESRI at 380 New York Street, Redlands, CA 92373-8100, USA. *ArcUser* is written for users of ESRI software. *ArcUser* is distributed free of charge to registered users of ESRI software.

# DEPARTMENTS


6 **Simple CAD Interoperability**
New build of ArcGIS for AutoCAD

6 **Access Spatial Features in Microsoft SQL Server 2008**
Support extended across ArcGIS 9.3 platform

8 **A Variety of Geocoding Solutions**
Options for desktop, server, mobile, and stand-alone implementations

9 **Extend Savings in the Field**
In-vehicle navigation solution ensures precise routing

9 **Learn More about ArcGIS on YouTube**

9 **Create Cross-Platform Internet Applications with Flex**

10 **Dramatically Better Performance**
ArcGIS 9.3.1 delivers fast Web applications and improved data sharing

11 **Seminar on Configuring and Deploying Effective Web Maps**

12 **The Top Nine Reasons to Use a File Geodatabase**
A scalable and speedy choice for single users or small groups

15 **Compressing versus Compacting**

## MANAGER'S CORNER

32 **Speak the Same Language**
Making a compelling case for GIS to business executives

35 **The Most Important Part of a GIS**
Make sure staff have the right skills with a training plan

## DEVELOPER'S CORNER

36 **Easy Access to Near Real-Time Data**
Looking at a methodology that generates aggregated live feeds for ArcGIS clients

38 **Utility Aids Developers and ESRI**
Generate API usage statistics on dependencies, versions, and calls

## HANDS ON

46 **Get a New Strategy**
Five easy ways to streamline geospatial metadata production

50 **Convincing the Chief**
Proving that time-based networks really work

56 **Asking the Right Questions**
Getting started using queries

## BOOKSHELF

58 **Why GIS Is a Great Investment for Government**
New book on decision support and public policy

58 **New Edition of Best-Selling GIS Text**
Workbook covers ArcGIS 9.3 release

## USERS

60 **It's Just Easier Now**
New support resources

61 **A Day in the Life**
Working in software development at ESRI

61 **ESRI International User Conference**
Be Part of the ESRI UC Plenary Session

## EDUCATION

62 **Flex-ible Web Site Serves More Data about Schools**
Federal data clearinghouse upgrades site

62 **Worldwide Forum for GIS Educators**
Many resources available at education community Web site

63 **Resources for Professionals, Scholars, and Students**
GIS bibliography tops 75,000 entries

63 **New ESRI Higher Education Head**
Director brings extensive expertise and experience

64 **New ESRI Authorized Instructors**

## END NOTES

66 **Combining Math, GIS, and Community Service**
Teacher inspires students to use GIS to solve real problems

# Simple CAD Interoperability

## New build of ArcGIS for AutoCAD

A new version of ArcGIS for AutoCAD greatly improves the ease with which users can share and use GIS content with AutoCAD files while preserving existing CAD workflows.

This free downloadable tool from ESRI offers simple interoperability that gives AutoCAD users access to enterprise GIS data and imagery published by ArcGIS Server within the AutoCAD environment. Data can also be prepared with AutoCAD for use in ArcGIS.

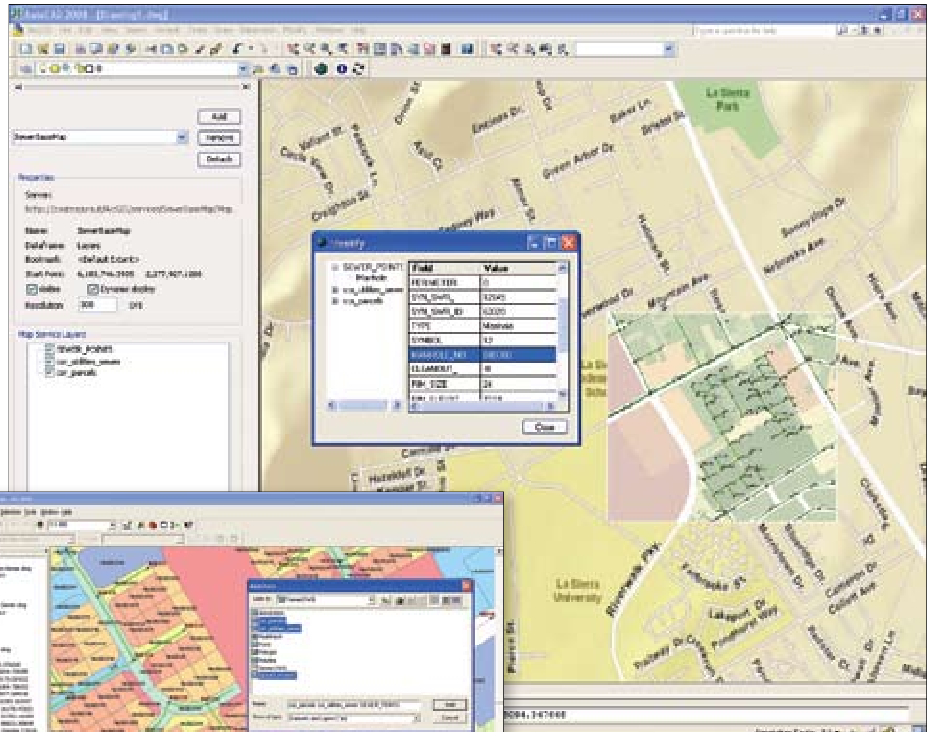
ArcGIS for AutoCAD Build 200 supports ArcGIS Server 9.3 cached map services, ArcGIS Server map services on secure servers, and free and premium map service content available from ArcGIS Online Services.

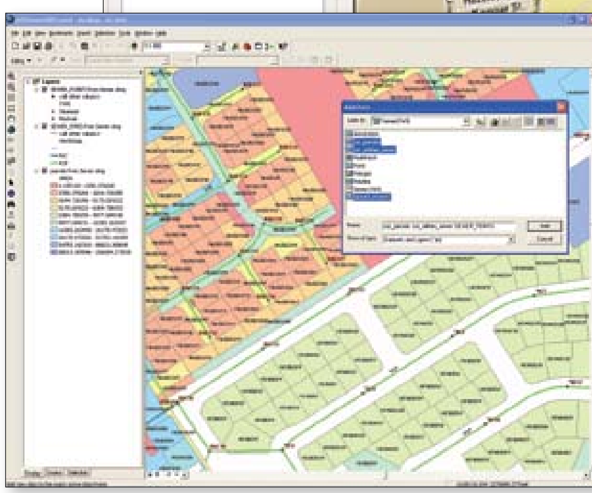
Users of this tool can view and query enterprise GIS information from public and private sites that use ArcGIS Server to publish map services over the Web. This provides CAD designers and engineers with information about the environment and infrastructure that supports design decisions. Accessed in AutoCAD without translating or converting the underlying GIS data, map services content is automatically projected in AutoCAD based on the coordinate system of the CAD drawing.

In addition, ESRI has developed a new data-encoding method called mapping specification for drawing (MSD), which has been implemented in the newest build of ArcGIS for AutoCAD and ArcGIS 9.3. This method allows users to create, manipulate, and define how CAD data is organized and attributed as GIS content while remaining true to existing CAD standards. Tools in ArcGIS for AutoCAD allow users to create and edit GIS feature classes within standard AutoCAD files and add attributes to any AutoCAD entity. Additional tools let users build CAD-based, GIS-ready applications.

AutoCAD files enhanced with MSD can be used directly as GIS content in ArcGIS Desktop, ArcGIS for AutoCAD, or custom AutoCAD applications that have implemented the data-encoding method. ArcGIS for AutoCAD is compatible with AutoCAD 2007, 2008, and 2009 and map services for ArcGIS Server 9.2 and above. To learn more about this free tool and download it, visit www.esri.com/autocadapp.

ESRI courses on this topic include *Working with CAD Data in ArcGIS Desktop,* an instructor-led Virtual Classroom course, and *Geoprocessing CAD Data with ArcGIS,* a free Web training seminar.





*Above: ArcGIS for AutoCAD viewing ArcGIS Online Street Map and sewer basemap content along with mapping specification for drawing (MSD) data exported from ArcMap but viewed inside AutoCAD. Left: An example of an ArcMap CAD direct read of MSD data.*

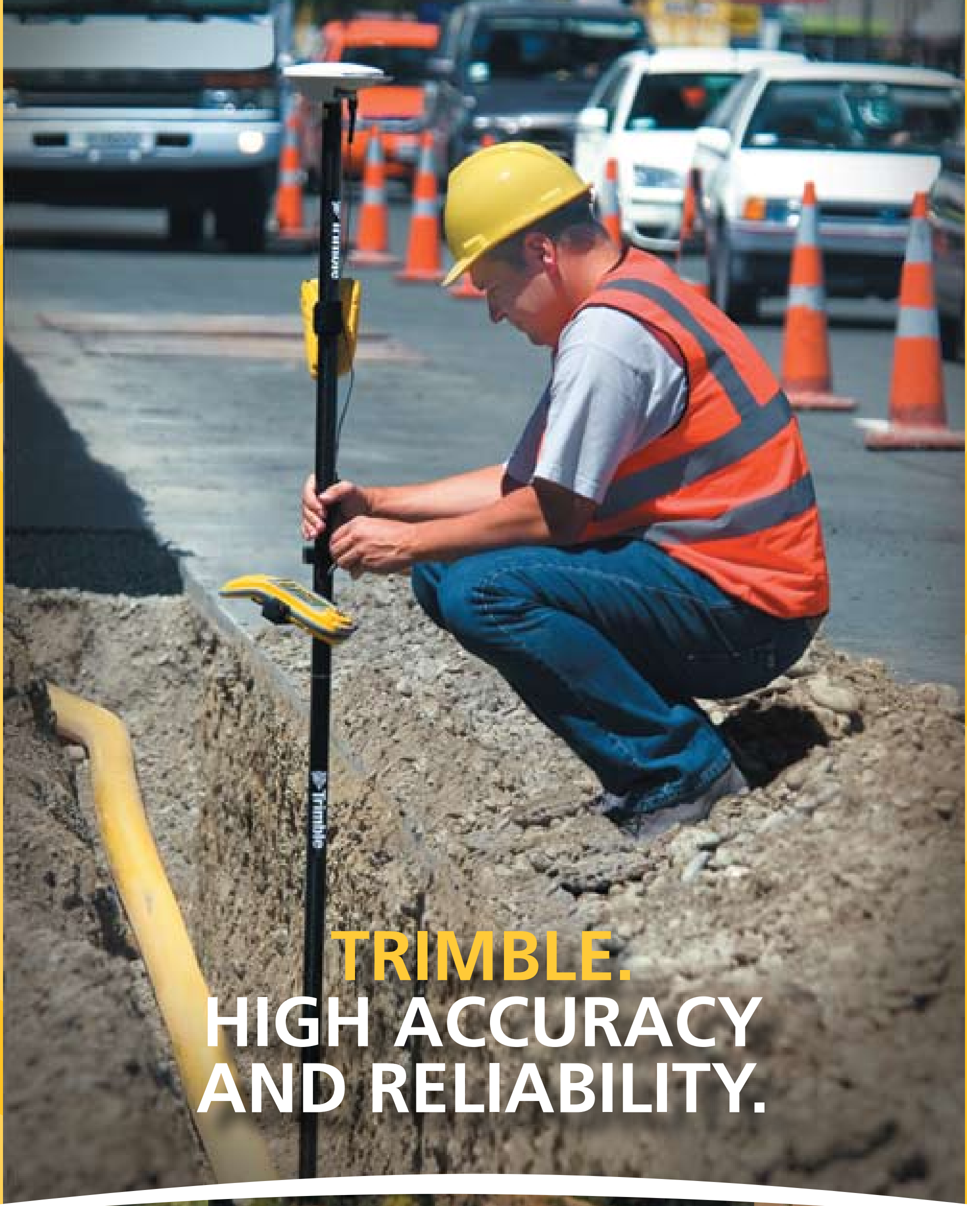
# Access Spatial Features in Microsoft SQL Server 2008

## Support extended across ArcGIS 9.3 platform

ArcGIS users can now perform Structured Query Language (SQL) queries and operations on spatial data within Microsoft SQL Server 2008. As the result of a multiyear working relationship between ESRI and Microsoft, spatial extensions to SQL Server 2008 let users integrate spatial data with other enterprise applications and seamlessly consume, use, and extend location-based analysis for enterprise-scale computing and Web collaboration.

With the introduction of Geography and Geometry, two new spatial types for Microsoft SQL Server 2008 that are supported by ArcGIS, GIS users will have SQL access to spatial features in SQL Server. ArcGIS Server 9.3 Enterprise enables ESRI's support for SQL Server 2008 to extend across the ArcGIS 9.3 platform including server, desktop, mobile, and online technology. For optimal performance with SQL Server 2008, ESRI recommends installing Service Pack 1 for ArcGIS 9.3. Learn more about ESRI's support for Microsoft SQL Server 2008 and view a demo that showcases ESRI's integration with SQL Server 2008 at www.esri.com/sqlserver2008.

For more information, ESRI offers *ArcGIS Server Enterprise Configuration and Tuning for SQL Server,* an instructor-led course.




You don't have to dig deep to discover everything Trimble has to offer. Incorporating the best technology, decimeter accuracy, and durability into our Mapping & GIS products, we put complete reliability at your fingertips. Since day one, we've been constantly developing and manufacturing cutting-edge GPS/GIS hardware and software products built to withstand the elements and heavy use, along with the technical support and customer service to back them up. All of this really gives Trimble users something to hold onto.

***Visit us at the ESRI International User Conference in San Diego, 13–17 July 2009. We are located at booth 1321.***

**Trimble**

www.trimble.com
store.trimble.com

# A Variety of Geocoding Solutions

## Options for desktop, server, mobile, and stand-alone implementations

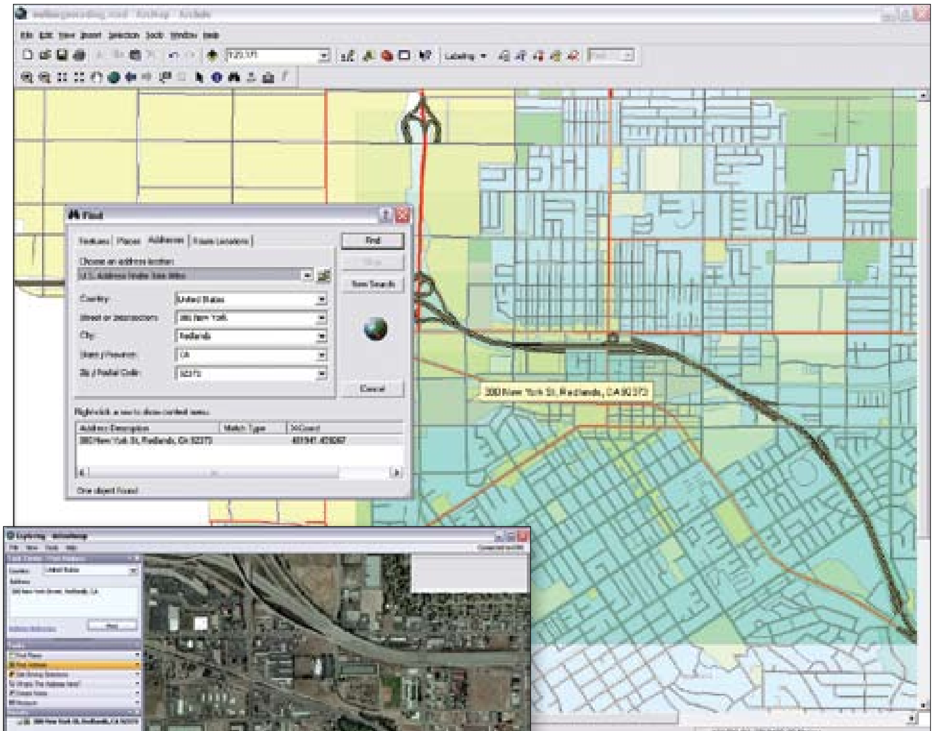
Incorporate geocoding capabilities using a variety of products that include ArcGIS Online; ArcGIS DataAppliance; ArcGIS Desktop; ArcGIS Server; and the new, stand-alone Address Coder software.

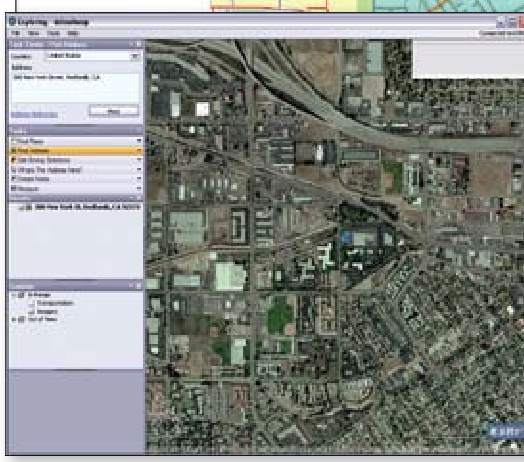
Geocoding links geographic coordinates to commonly available data such as addresses and postal codes to associate places with information on customers, infrastructure, and other assets to understand relationships between data points and other location information data such as flood zones, school districts, or electoral boundaries.

The newly released ArcGIS Online World Geocoding service, available for ArcGIS Desktop and ArcGIS Server, offers users free geocoding and place-finding capabilities. This standard ArcGIS Online service is available to ArcGIS users at no cost for internal or external, noncommercial use and includes street address locators for North America (U.S. and Canada) and Europe and a place-name locator for the world. The ArcGIS Online World Geocoding service supports geocoding, reverse geocoding, and limited batch geocoding. A subscription-based version of this service for commercial use is also available and includes the ability to batch geocode up to 25,000 addresses per subscription.

The World Geocoding service available through ArcGIS Online uses the most recent commercial street data from Tele Atlas, including coverage for North America (U.S. and Canada) and more than 20 European countries. Web applications developers can quickly leverage these services using various ArcGIS APIs including SOAP, REST, JavaScript, and Silverlight, to support their geocoding needs. For organizations that want to publish their own geocoding services using ArcGIS Server, the ArcGIS Data Appliance offers the same locator services and reference data along with other 2D and 3D map collections.

As part of core functionality, ArcGIS Desktop provides access to specific locators for the United States, Canada, and Europe along with free locator templates. For custom applications, users can buy or build locators based on their reference data or purchase StreetMap Premium, which includes its own locators for North America (U.S. and Canada) or Europe. StreetMap Premium provides licensing levels for ArcGIS Desktop as well as ArcGIS Server. Users who don't need the latest available reference data can also leverage the StreetMap North America dataset, containing five-year-old Tele Atlas street data that is included with *ESRI Data & Maps,* which ships with all ArcGIS products.





*Above: ArcGIS Desktop provides access to three geographically specific address finders. Left: The geocoding services available through ArcGIS Online use the most recent commercial StreetMap Premium data from Tele Atlas.*

A solution for direct mail managers, marketers, fund-raisers, and others is also available. Address Coder is a stand-alone geocoding and data-appending software that will help these users segment and target U.S. address lists to effectively and efficiently reach customers. Address lists can be appended with latitude-longitude coordinates, FIPS codes, or ESRI's Tapestry Segmentation codes. Two versions of the product are available—Address Coder and Address Coder Premium. The premium version uses the 45-million-record Tele Atlas Points database to geocode at the "rooftop" level, followed by the traditional geocoding methods used by the standard version of Address Coder. Optional add-ons of Tapestry Segmentation data enable users to segment, manage, and target address lists based on demographics and lifestyles of consumers. Built with ArcGIS Engine and ESRI's geocoding locator technology, Address Coder provides the proven address-matching concept that is already part of the ArcGIS technology.

Address Coder's step-by-step process enables users to geocode address records without extensive training. Using customization options, the geocoding process can be tailored to an organization's specific requirements. A variety of geographic areas, from the nation to a single state, can be licensed.

The application solution chosen will depend on security and other requirements. Developers that want to deploy public-facing Web applications or databases in which address security is not a main concern can take advantage of the ArcGIS Online World Geocoding service along with the World Street Map service. For organizations such as hospitals and banks that need to keep address lists private and secure behind a firewall, ArcGIS Desktop, combined with StreetMap Premium, ArcGIS Data Appliance, or Address Coder, will address these needs. Organizations that manage large U.S. address lists for marketing and other mailings benefit from the functions in Address Coder.

For more information, see www.esri.com/arcgisonline or www.esri.com/coder or take the Web course *Geocoding with ArcGIS Desktop.*

# Extend Savings in the Field

## In-vehicle navigation solution ensures precise routing

Guide drivers to optimized stops and keep them on schedule with ESRI's in-vehicle navigation solution. ArcLogistics Navigator is specifically designed for trucking, fleet, and logistics applications. It creates a complete solution for organizations that need to plan optimum routes and schedules on the desktop and ensure these routes are followed in the field. ArcLogistics Navigator will help fleets use less fuel, reduce vehicle wear and tear from unnecessary miles driven, and improve customer satisfaction by meeting tight time windows.

Organizations that use it typically save 15 to 20 percent in fleet-related costs within months of implementation. Because ArcLogistics Navigator is tightly integrated with ArcLogistics, the powerful solvers in ArcLogistics desktop consider customer time windows, vehicle capacity, driver specialty, and the nature of the street network when creating optimized routes. Route planners can send optimized stops directly to in-vehicle devices. This ensures that drivers follow the exact streets chosen for the route.

Minimize the time and mileage caused by missed turns and stops with the audible turn-by-turn directions, constant updates on the vehicle's location, and on-screen map provided by ArcLogistics Navigator. Dispatchers can provide drivers with barrier information, such as road closures, construction, or traffic incidents, as well as which roads should be used in route calculations, based on the kind of road or vehicle type or size. Because it's a GPS application, should drivers stray from the route, ArcLogistics Navigator will reroute them to the next stop in the optimized route.

ArcLogistics Navigator includes NAVTEQ map data for the United States, Canada, and Europe. The NAVTEQ dataset for ArcLogistics Navigator includes the latest street geometry with navigational attributes that facilitate turn-by-turn directions and enable in-dash vehicle and portable navigation devices, route planning, and map display services. NAVTEQ's extensive street database provides ArcLogistics users with a high level of accuracy and helps them find locations and efficient routes to their destinations.

ArcLogistics Navigator runs on Windows Vista, Windows XP, and Windows Mobile devices (Windows Mobile 5 and 6). Learn more about ArcLogistics Navigator at www.esri.com/arclogistics. Users outside the United States should contact their ESRI international distributor (www.esri.com/distributors).

ESRI offers a free Web training seminar, *Introduction to ArcLogistics Navigator.*

## Learn More about ArcGIS on YouTube

Visit the ESRI Channel on YouTube to view videos on ArcGIS software products. Popular videos on ArcGIS include

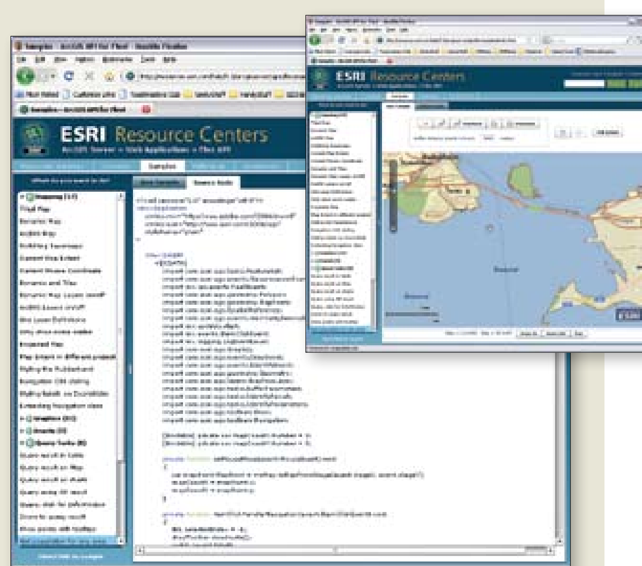
- What's New in ArcGIS 9.3
- ArcGIS API for Microsoft Silverlight—A Sneak Peek
- ArcGIS 9.3: Disseminate Information to the Field Using ArcGIS Mobile
- Georeferenced PDFs in ArcGIS Desktop 9.3
- ArcGIS Explorer 900 Preview

Search on esritv to view the more than 100 videos available on the ESRI Channel at YouTube.

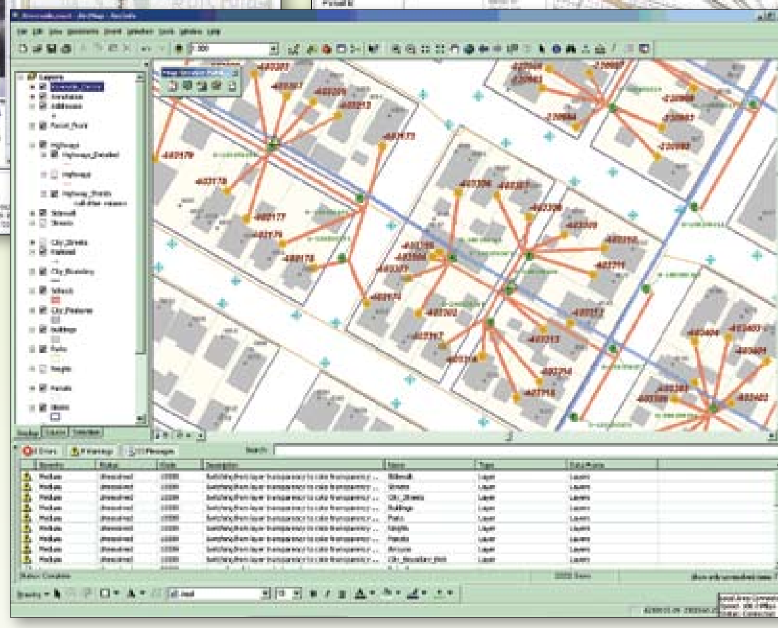

## Create Cross-Platform Internet Applications with Flex

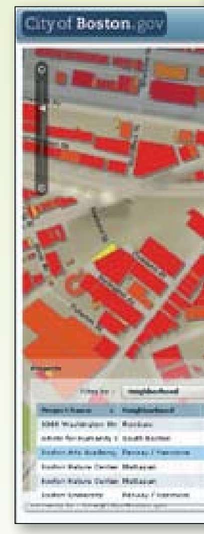
Use the highly productive Flex framework for building and maintaining expressive applications on top of ArcGIS Server. Flex is a free open source framework for creating applications that deploy consistently on all major browsers, desktops, and operating systems. The new version (1.1) of the ArcGIS API for Flex, now available to download from the ESRI Resource Center, allows Adobe Flex developers to display maps from ArcGIS Server and ArcIMS, execute queries against ArcGIS Server services, and perform GIS analysis through geoprocessing services. The ESRI Resource Center provides many samples with code and new help topics. This version includes bug fixes and graphics performance improvement.

Learn more by taking the free ESRI training seminar *Building Rich Internet Applications with ArcGIS API for Flex*.










*Right: Use tools on the Map Service Publishing toolbar in ArcMap to analyze map characteristics that affect performance and generate a comprehensive list of tips for tuning a map prior to publishing it.*

# Dramatically Better Performance

## ArcGIS 9.3.1 delivers fast Web applications and improved data sharing

ArcGIS 9.3.1, a focused minor release scheduled for the second quarter of 2009, provides a framework for publishing great Web maps, improves data sharing, and enhances support for Java developers.

### High-Performance Web Mapping

This release presents a new option in the author-serve-use workflow; map documents can now be analyzed and then optimized to create faster, higher quality, dynamic map services. As a result, map service and Web application end users will experience dramatically improved online performance including much faster drawing speeds and better-looking maps. At 9.3.1, maps can be fine-tuned for faster performance using the new Map Service Publishing toolbar in ArcMap. The toolbar provides a straightforward set of tools for analyzing and tuning the map, previewing the results, and publishing the optimized map to ArcGIS Server directly from ArcMap.

Optimized map services created with the Map Service Publishing toolbar not only draw faster, they have increased antialiasing options for drawing smoother line and text edges. End users will notice improved map quality in optimized map services: feature edges are sharper, labels are more legible, and color transparency is improved. When published from this toolbar, a map service definition (.msd) file becomes the basis for the service and uses a new, faster drawing engine. This optimized service supports many of the commonly used data types including enterprise and file geodatabase, SDC, shapefile, street map, and raster. It supports standard layer symbology including graduated colors and symbols, proportional symbols, and unique values. It also supports the standard ESRI labeling engine as well as numerous graphic elements and two-dimensional symbols.

Map caching is still recommended for optimal service performance, particularly for basemaps and other layers that don't change frequently. Optimized services can be cached and help reduce the time needed for caching. Optimized services are best suited for dynamic map services where data changes more frequently or real-time data display is required. Both cached and optimized services can be combined to create high-performance Web mapping applications.

### Better Data Sharing

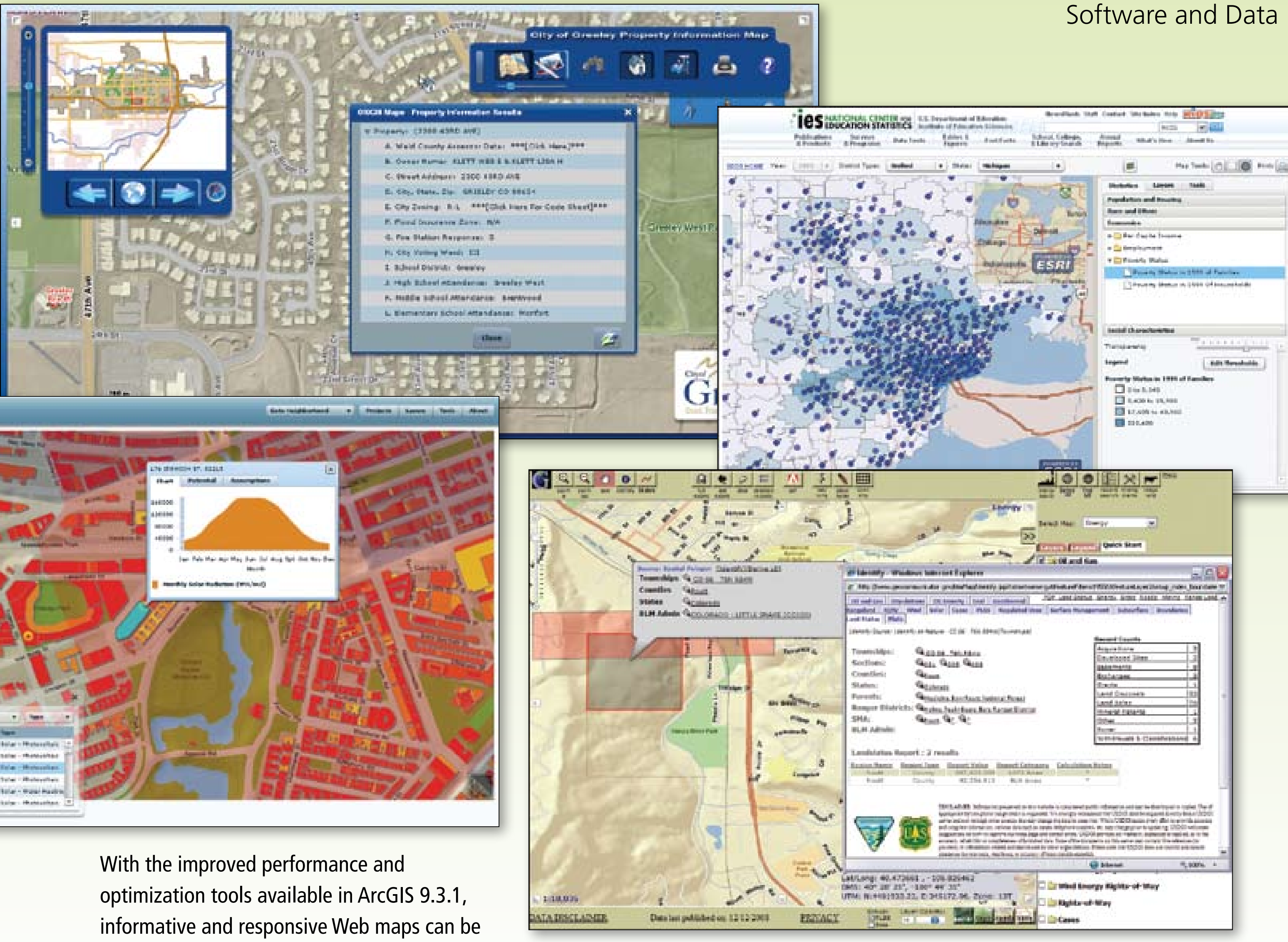
New layer packages make it easy to share data. Bundle layers in a map document and the associated data in a package that can be easily used by others who have either ArcGIS Desktop or ArcGIS Explorer. These files can be shared using file share or e-mail or by publishing these layers through ArcGIS Online Web services.

ArcGIS Online capabilities have been extended to allow upload and download of shared layers and data to enable sharing with groups and communities online.

### Enhanced Support for Java Developers

With this release, support for Java developers has been extended. Developers can now change or enhance the behavior of ArcObjects, create their own ArcObjects, and extend ArcGIS Server.

Java developers who want to extend the ArcGIS framework in the ArcGIS Desktop/



With the improved performance and optimization tools available in ArcGIS 9.3.1, informative and responsive Web maps can be more easily configured and deployed.

ArcGIS Engine (Java SE) and ArcGIS Server (Java EE) platforms will be able to create the following extensions:

- Custom geoprocessing tools
- Server object extensions (SOEs) for ArcGIS Server
- Class extensions for custom behavior
- Custom renderers for customized rendering of data
- Plug-in data sources
- Custom layers

Eclipse integrated development environment (IDE) support will also be provided in wizards that will generate boilerplate code based on the developer specifications. This will facilitate quick and easy development of extensions. ArcGIS 9.3.1 will also include an autodeploy feature that will allow Java developers and their end users to automatically deploy Java extensions.

### Other Features for Developers

ArcGIS 9.3.1 fully supports Microsoft Silverlight to allow developers to create rich Internet applications (RIAs) that incorporate animation, vector graphics, and audio-video playback.

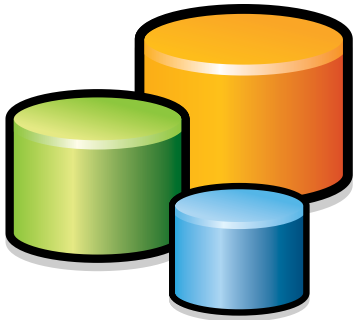
### Upgrade Easily

Users who have ArcGIS 9.3 installed can upgrade to ArcGIS 9.3.1 without uninstalling ArcGIS 9.3. ArcGIS 9.3.1 is 100 percent compatible with ArcGIS 9.3 for all aspects of ArcGIS (including geodatabases, maps, and APIs), so users can easily migrate or work in environments where both versions are in use.

ArcGIS 9.3.1

## Seminar on Configuring and Deploying Effective Web Maps

In May 2009, ESRI will offer a free, nationwide seminar to help ArcGIS users learn how to easily create high-quality, fast Web applications. This seminar will show users, step by step, the best practices for creating efficient map services and focused Web applications using new optimization and configuration tools and sample applications available with ArcGIS 9.3.1. Visit www.esri.com/webmaps for more information.



# The Top Nine Reasons to Use a File Geodatabase

## A scalable and speedy choice for single users or small groups

*By Colin Childs, ESRI Education Services*

Whether you are working with large or small datasets, file geodatabases optimized for use in ArcGIS are ideal for storing and managing geospatial data. Whether you are working on a single-user project or a project involving a small group with one or several editors, you really should consider using a file geodatabase rather than a personal geodatabase or collection of shapefiles. File geodatabases offer structural, performance, and data management advantages over personal geodatabases and shapefiles.

| | |
|---|---|
| **Structural** | 1. Improved versatility and usability<br>2. Optimized performance<br>3. Few size limitations |
| **Performance** | 4. Easy data migration<br>5. Improved editing model<br>6. Storing rasters in the geodatabase |
| **Data Management** | 7. Customizable storage configuration<br>8. Allows updates to spatial indexes<br>9. Allows the use of data compression |

### 1 Improved versatility and usability

The file geodatabase is stored as a system folder that contains binary files that store and manage geospatial data. It is available at all ArcGIS license levels and functions in the same fashion on Windows and UNIX (Solaris and Linux) operating systems. This storage system is based on relational principles and provides a simple, formal data model for storing and working with information in tables.

Open a file geodatabase folder in Windows Explorer, and it looks like any other folder. You can view the files it contains: geographic data, attribute data, index files, lock files, signature files, and other files. Each feature class or table in the geodatabase is stored in two or more files.

### 2 Optimized performance

The data structure of a file geodatabase is optimized for performance and storage. Although individual feature classes can be as large as 1 terabyte (TB) in size and contain hundreds of millions of features, they still provide fast performance. File geodatabases significantly outperform shapefiles for operations involving attributes and allow scaling of dataset size limits way beyond those of shapefiles.

### 3 Few size limitations

Database size is limited only by available disk space. By default, individual tables and feature classes can be up to 1 TB. With the use of configuration keywords, this can be expanded to 256 TB.

### 4 Easy data migration

Because file geodatabases and personal geodatabases are both designed to be edited by a single user and do not support geodatabase versioning, data migration between them is easy.

### 5 Improved editing model

File geodatabases do not lock down the whole geodatabase if a user is editing a feature class. An edit model similar to that used for shapefiles is deployed. This model supports a single data editor and many data viewers concurrently. Stand-alone feature classes, tables, and feature dataset contents can be edited by different editors simultaneously without the entire geodatabase being locked. If a feature class in a feature dataset is being edited, all feature classes in that feature dataset are unavailable for editing, but features may still be viewed and selected in ArcMap.

### 6 Storing rasters in the geodatabase

Raster storage in a file geodatabase shares functionality from both the ArcSDE geodatabase and the personal geodatabase. Managed raster data is stored in the same way as in an ArcSDE geodatabase, and unmanaged raster data is stored in the same way as in a personal geodatabase.

Managed raster data is subdivided into small, manageable areas called tiles, stored as binary large objects (BLOBs) in the database. The tiling is automatic and invisible to end users.

These tiles are indexed and pyramided for fast display performance. Pyramiding allows the geodatabase to fetch only data at the specified resolution or level required for display.

Unmanaged rasters are maintained by users. Only the path to the location on the disk where the raster dataset is stored is maintained in the file geodatabase.

### 7 Customizable storage configuration

When creating a dataset, apply optional configuration keywords to customize data storage. Keywords optimize storage for a particular type of data to improve storage efficiency and performance.

| Property | Settings |
|---|---|
| File geodatabase size | Technically no limit |
| Table or feature class size | 1 TB (default)<br>256 TB (with keyword) |
| Number of feature classes and tables | 2,147,483,647 |
| Number of fields in a table or feature class | 65,534 |
| Number of rows in a table or feature class | 4,294,967,295 |
| Geodatabase name length | Operating system limits for a folder name |
| Table or feature class name length | 160 characters |
| Field name length | 64 characters |
| Character field width | 2,147,483,647 |

*File geodatabase parameters*

| Action in ArcCatalog | Method |
|---|---|
| Copying stand-alone feature classes or feature datasets | Use ArcCatalog's Copy and Paste commands. |
| Copying entire geodatabase | Use the Export > XML Workspace Document command to export the entire database to an XML file. Create a new, empty file geodatabase. Import > XML Workspace Document to import the data and schema from the XML file into a new file geodatabase. |
| Converting from low- to high-precision data | Automatically convert with Copy/Paste and Export to XML Workspace Document. |
| Migrating domains | Copy referenced feature class using Copy/Paste. |
| Migrating unreferenced domains | Use the Export > XML Workspace Document command to export the entire database to an XML file. Import > XML Workspace Document choose domain to import from the XML file. |
| Incorporating shapefiles, coverages, and CAD data | Use Export > To Geodatabase or Import > To Geodatabase command. |

*Methods for moving data from a personal to a file geodatabase*

In most cases, the DEFAULTS keyword is used. Use the keywords shown in the accompanying table if the dataset exceeds 1 TB or is less than 4 GB. If no configuration keyword is specified, the DEFAULTS keyword is used.

## 8 Allows updates to spatial index settings

Spatial indexes are used by ArcGIS to quickly locate features when you display, edit, or query data. An appropriate spatial index is important, especially when you are working with large datasets. While the spatial index of a personal geodatabase feature class uses a single grid size that cannot be modified, the spatial index of a file geodatabase feature class uses as many as three grid sizes, which can be modified. Additional grids allow feature classes with features of very different sizes to be queried more quickly.

ArcGIS automatically rebuilds the spatial index at the end of some update operations to ensure the index and its grid sizes are optimal. However, in some rare cases, you may need to manually recalculate the index.

## 9 Allows the use of data compression

Vector data can be stored in a file geodatabase in a compressed, read-only format that reduces storage requirements. Compression reduces the geodatabase's overall footprint on disk without reducing the performance. Once compressed, display and query performance are comparable to uncompressed data. Compressed data is in a direct-access format, so there is no need to uncompress the data because ArcGIS and ArcReader can read it directly.

*Continued on page 14*

# The Top Nine Reasons to Use a File Geodatabase

*Continued from page 13*

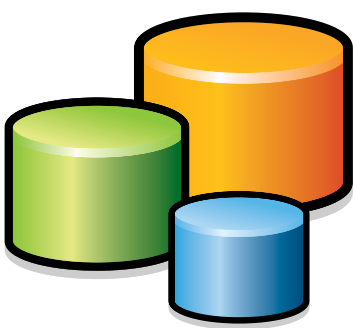
| Sample data | Number/Type of features | Number of fields | Uncompressed size | Compressed size | Compression ratio (1:x) |
|---|---|---|---|---|---|
| Germany streets | 7,118,614 lines | 83 | 2.3 GB | 511 MB | 4.5 |
| U.S. census blocks | 8,205,055 points | 11 | 705 MB | 162 MB | 4.4 |
| Europe rails | 383,531 lines | 12 | 58 MB | 17 MB | 3.4 |
| Calgary addresses | 285,285 points | 8 | 21 MB | 7.4 MB | 2.8 |
| Calgary buildings | 319,000 polygons | 9 | 48 MB | 20 MB | 2.4 |
| Europe water | 232,375 polygons | 10 | 176 MB | 125 MB | 1.4 |

*Effects of compression by feature type and numbers*

Compression is ideally suited to mature datasets that do not require further editing. However, if required, a compressed dataset can always be uncompressed and returned to its original, read/write format. The compression method applied is lossless, so no information is lost. One of the most important factors affecting spatial data compression is the average number of vertices per feature. As a general rule, the fewer vertices/features, the greater the compression. The tables above illustrate the effects of applying compression.

**Ready to Try File Geodatabases?**

The file geodatabase provides a widely available, simple, and scalable geodatabase solution for all users that can work across operating systems. It can scale up to handle very large datasets and still provide excellent performance. Its efficient data structure is optimized for performance and storage and uses about one-third the feature geometry storage required by shapefiles and personal geodatabases. File geodatabases also allow users to compress vector data to a read-only format that further reduces storage requirements.



| Keyword name | Keyword setting | Usage |
|---|---|---|
| DEFAULTS | 1 TB | Default settings |
| TEXT_UTF16 | 1 TB | Optimizes storage for non-Latin alphabet text |
| MAX_FILE_SIZE_4GB | 4 GB | Restricts dataset to a maximum size of 4 GB; stores datasets less than 4 GB more efficiently than DEFAULTS keyword |
| MAX_FILE_SIZE_256TB | 256 TB | Used to create a dataset that is up to 256 TB in size |

*Keywords for customizing data storage*

| Action | Effect on spatial index |
|---|---|
| Create empty feature class. | Spatial index is created, but remains in unbuilt state. Grid sizes are set to 0,0,0. |
| Add/Create features in empty feature class. | Initial grid sizes 0,0,0 are automatically rebuilt as feature properties are updated. |
| Add different-sized features to feature class. | Manually update the index. The Indexes tab appears in the Feature Class Properties dialog box. Click the Recalculate button. |
| Load data using simple data loader or Append tool. | The spatial index is built as the final step of the loading process. Appropriate grid sizes are calculated for the new added features. |
| Import data. | The spatial index is automatically computed for the new feature class. |
| Copy/Paste feature class personal to a file geodatabase. | The spatial index is automatically rebuilt. |
| Copy/Paste feature class from file or ArcSDE geodatabase. | The spatial index is copied from the source, not recomputed. |
| Compress data. | An alternate indexing method is automatically applied and cannot be modified. |
| Uncompress data. | Precompression index is automatically reestablished. |

*File geodatabase and spatial indexes table*

| Compress | Result |
|---|---|
| Full geodatabase | All feature classes, feature datasets, and tables compressed |
| Stand-alone feature classes | A single feature class compressed |
| Feature dataset | All feature classes in the feature dataset compressed |
| Raster dataset | Compression already applied through pyramid creation |

*Effects of compression on data storage*

| Sample data | Uncompressed size | Compressed size | Compression percentage |
|---|---|---|---|
| U.S. census block centroids | 705 MB | 162 MB | 77 |
| California roads | 329 MB | 83 MB | 74.7 |
| Manhattan, NY parcels | 4.42 MB | 1.92 MB | 56.6 |
| Vegetation data | 3.31 MB | 2.32 MB | 30 |
| Riverside, CA buildings | 644 KB | 314.5 KB | 51.2 |

*Effects of compression by percentage*

# Compressing versus Compacting

These two operations are conceptually similar in that each can result in more compact storage, but as applied to file geodatabases, these are two unrelated operations.

**Compaction**

- Tidies up the storage of records in files by reordering them and eliminating free space
- Is recommended if data is frequently added and deleted
- Can reduce file sizes and improve performance
- Does not affect read/write capability
- Should be performed regularly

**Compression**

- Reduces storage requirements
- Improves database performance
- Makes database or feature classes read-only
- Should be performed as needed

**Learn More**

Several courses on building and using geodatabases are offered by ESRI. Visit www.esri.com/training to learn more about these offerings.

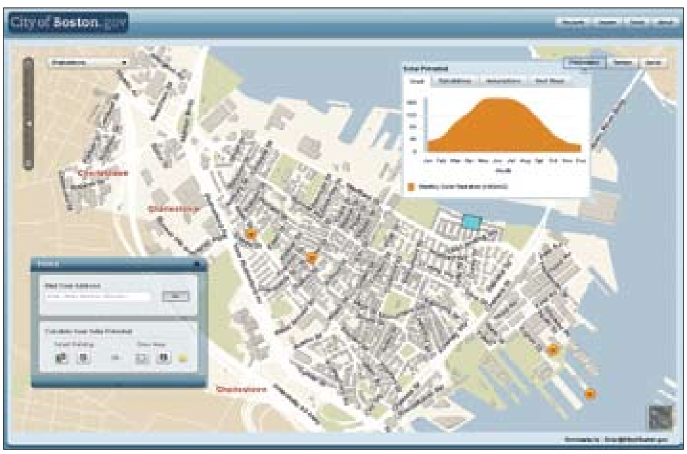
- *Building Geodatabases,* an instructor-led course
- *Creating and Editing Geodatabase Features with ArcGIS Desktop (for ArcEditor and ArcInfo),* a Web course
- *Introduction to the Multiuser Geodatabase,* an instructor-led course
- *Creating, Editing, and Managing Geodatabases for ArcGIS Desktop,* a Web course

# The Next Step

## The importance of building geospatial infrastructures

Like no other time in recent history, our world is challenged. Disease, environmental deterioration, disasters, and now the widespread disruption of financial markets test the resourcefulness of society.

Over the past 40 years, GIS has evolved from a tool for managing projects to a framework for understanding and responding to problems on scales ranging from the local to the global. The geographic approach has become an important methodology for integrating data and information and enabling better decision making. The availability of quality geospatial data, together with improvements in software and hardware performance, has made these advances possible.



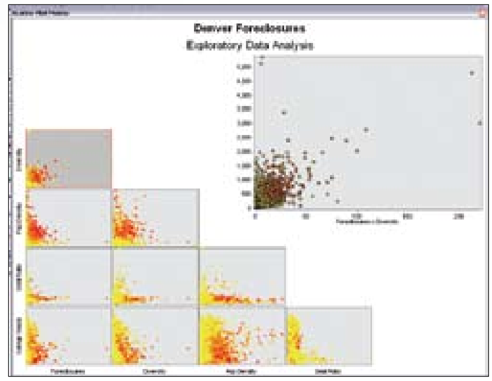

*The Solar Boston Web site uses geospatial data and high-performance, application-focused Web mapping to encourage the adoption of solar energy in the city of Boston, Massachusetts. Visitors can use tools at the site to calculate the solar potential of building rooftops and the annual cost savings that could be realized from installing solar panels.*

With the move to an object-oriented platform, ArcGIS is better able to abstract and model the world, representing and integrating information about complex systems and modeling their behaviors. This is true whether the subject under study is as broad as an ocean or limited to a neighborhood.

The development of spatial data infrastructures (SDIs) represents the next logical step in the expansion of GIS use for data management and decision support. SDIs use accepted data and metadata standards in the creation of well-documented foundation datasets. Used with constantly updated operational data, SDIs make data more accessible and useful for specific tasks and analyses and save time while sharing costs. SDIs, together with GIS software, unlock the information contained in the terabytes of measurements, images, transactions, and other data stored in digital form by placing it in a geographic context.

The phenomenal growth of the Internet has multiplied the value of SDIs by enhancing the dissemination of data and information products. The newest release of ESRI software, ArcGIS 9.3.1, is focused on making information more consumable using the Internet. It supplies tools for configuring and deploying responsive and informative Web maps that help users accomplish specific tasks.

In February 2009, the Statistical Office of the European Communities (Eurostat) awarded a contract for the development of the technical




*With new tools in ArcGIS, such as the regression analysis tools, vast data inventories can be placed in a geographic context and analyzed. This scatterplot matrix diagram is used for exploring data on foreclosures to discover if there is any relationship between variables preparatory to effectively modeling it.*

components of a Web-based GIS. The contract went to a consortium that based its solution on ESRI technology.

These components will comply with the provisions of the Infrastructure for Spatial Information in Europe (INSPIRE). In establishing INSPIRE, the European Commission recognized the importance of quality georeferenced information to the understanding of the complex interactions between human activities and environmental pressures and impacts.

Two articles in the Focus section of this issue of *ArcUser* magazine provide additional examples of the value of building geospatial infrastructures to address complex problems and provide tangible benefits.

Maintaining water quality is essential to the health of the environment. Although water quality monitoring has been ongoing for decades, this abundance of measurement data cannot be translated into effective regulation and remediation action if it is not accessible, placed in geographic context, and amenable to analysis.

The staff of Region 4 of the U.S. Environmental Protection Agency developed a geodatabase that manages current and historical water quality data and allows for rapid and flexible inquiry, analysis, and dissemination of this data and the information derived from it. This geodatabase, loaded into an ArcSDE server, uses feature classes, reformatted tables, and relationship classes. Information can be viewed as layer files generated from query definitions or queried by feature. This information is available from the desktop or distributed as ArcReader projects.

The benefits accrued from a geospatial infrastructure are greatly multiplied at larger scales as demonstrated by the marine SDI developed by the Portuguese Instituto Hidrografico. The SDI created by this naval organization integrates an abundance of sea monitoring data, prediction data, navigation charts, and base data using international data format standards and data models. A fully stipulated data policy and metadata for all geospatial data ensure data quality and promote data reuse. A wide range of information products generated for public, private, and military use are widely disseminated through Web portals. In addition, the SDI provides ad hoc decision support for the navy.

As these articles show, GIS professionals will play a more important role than ever in helping understand complex systems. With the development of SDIs, GIS professionals will be better able to apply GIS to transform data into knowledge. Aided by increasingly powerful tools in GIS, they can gain a better understanding of the world's complex systems and help develop a more sustainable future.


Fire risk assessment. Forest composition. Access routes. Whether you're investigating areas for fire potential, analyzing areas for burn severity, or determining how to route fire crews, it's important to have all the information you need about a forested area. ENVI gives you the tools you need to you quickly and easily analyze imagery and add timely information to your geodatabase. With automated workflows, feature extraction tools and integration with ArcGIS®, ENVI makes advanced image processing easy and delivers scientifically accurate results you can count on.
Image Processing that delivers fast and accurate results –
Because behind every pixel there's a person.
ITT
Engineered for life
ITT, the Engineered Blocks, and "Engineered for life" are registered trademarks of ITT Manufacturing Enterprises, Inc., and are used under license. ©2009, ITT Visual Information Solutions
Other names and logos are the property of their respective owners.
ENVI
Communications • Sensing & Surveillance • Space • Advanced Engineering & Integrated Services

# A Geospatial Foundation

## Public, private, and military applications flow from SDI

*By Miguel Bessa Pacheco, Instituto Hidrografico, Portuguese Navy*

The marine spatial data infrastructure (SDI) developed by the Portuguese Instituto Hidrografico (IHPT) provides information to decision makers and information products for environmental protection activities, research and development, private industry, military activities, and public information.

IHPT is the naval organization responsible for producing official nautical paper and electronic charts as well as conducting studies and research in marine-related disciplines such as physical oceanography, hydrography, marine geology, chemical oceanography, and navigation safety.

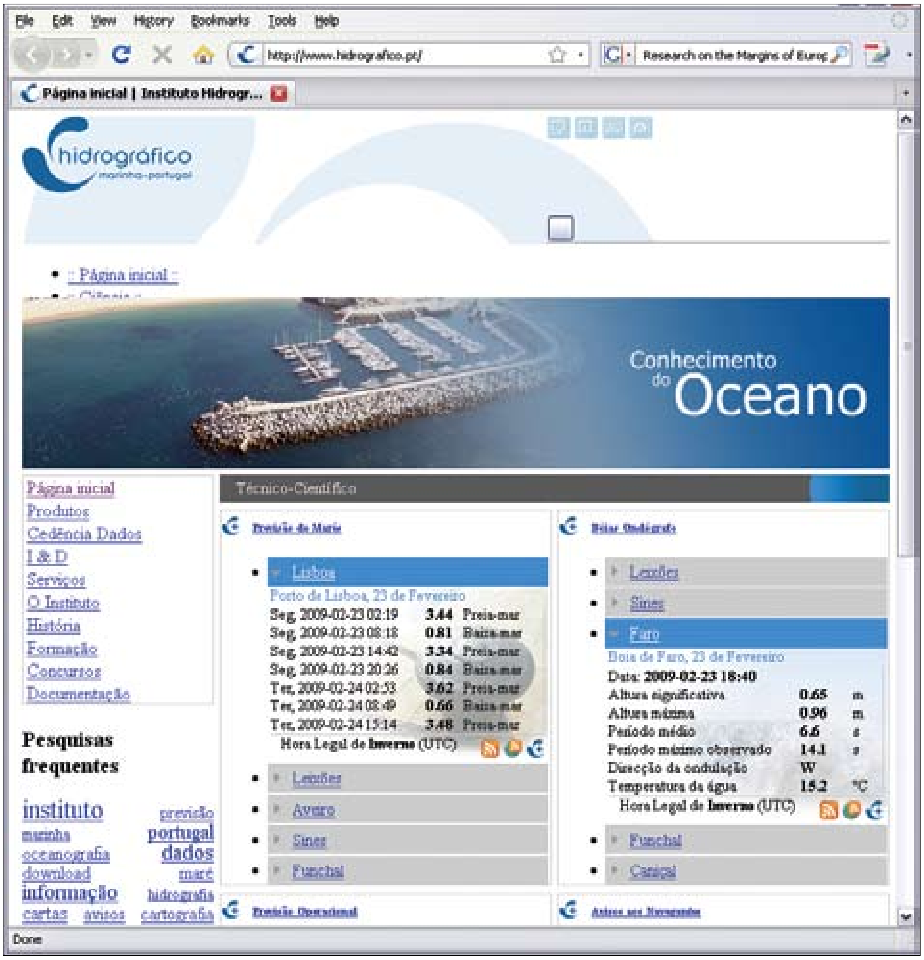
For the last several years, IHPT has been developing an SDI called IDAMAR (an acronym in Portuguese for spatial data infrastructure for the marine environment) to support the production of technical and scientific data and information product management. It began as a departmental GIS named SIGAMAR, but the scope of the GIS was subsequently broadened, and the IDAMAR SDI now also provides the institute with the ability to respond to ad hoc requests for information from decision makers.

### IDAMAR SDI Architecture

To conform with military communications security rules, the IDAMAR SDI is actually composed of two similar systems: one connected to the Internet and one connected to a private military network. The public portion, available to all users, includes communications networks, databases, metadata, software, hardware, specialized human resources, outreach and support, data policy, internal data management processes, distributable information products, and online services.

#### *Communications networks*

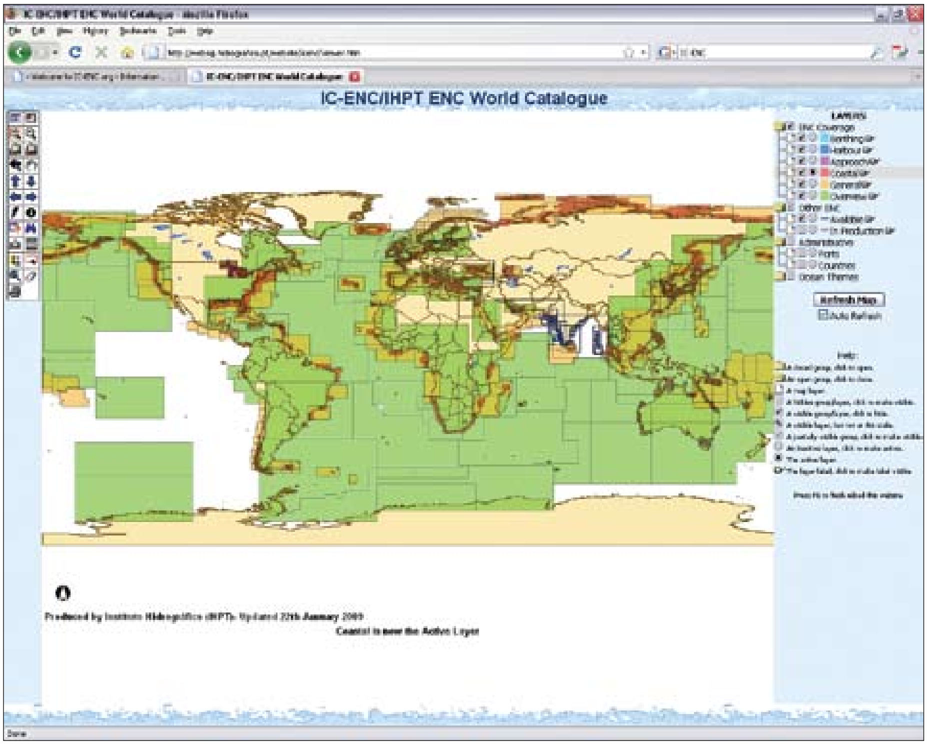
Three communications networks support data transfer and online access to the SDI: an Internet connection, a private unclassified military network, and a private classified military network. The Internet connection supports data acquisition from several environmental sensors (e.g., wave buoys, radar stations) and the public dissemination of information products through www.hidrografico.pt. The private military networks provide access to the full system and support specific data and information requests. These networks support all internal processes for data and information product management.




*Information products are publicly disseminated and are available from the public Web site at www.hidrografico.pt.*

#### *Databases and data models*

Several databases were developed using either DBMS- or file-based systems. The choice of system was based on the type of data stored and how that data could be most efficiently used. Data models for DBMS storage were internally developed for information processes except for chemical lab analysis data. A commercial laboratory information management solution, Thermo




*The Electronic Navigation Chart (ENC) World Catalog is one of the most relevant data catalogs available.*

Nautilus LIMS, was acquired and extended so chemical data could be easily integrated with the entire system. Internally developed data models (when applicable) follow the S-57 standard for hydrographic data transfer. *[S-57 is a digital data format standard.]* The most relevant developed data model supports the hydrographic data warehouse (HDW). This database stores bathymetric soundings acquired by the IHPT and represents a major improvement in the cartographic production process because it reduces production time, eliminates procedures susceptible to human error, and improves the quality of the final product.

Data stored includes data about the sea state (e.g., wave height, wave period, wave direction, and sea temperature) from ocean buoys; tide predictions and observations, horizontal control points; nautical chart and cell coverage; chemical analysis of seawater and sea bottom sediments; bathymetric navigation warnings; and medium-resolution satellite imagery. Not all data was supplied by IHPT—some data is related to activities of the Portuguese Navy.

***Data policy***

A data policy document sets out rules that govern data management and access in the IDAMAR SDI. This document stipulates policies for data classification, data access (both format and eligibility), and the associated costs. Some datasets are freely available to the public: near real-time sea state data; water temperature; sea state predictions for locations in the Atlantic and near Portugal; tide predictions for all principal and secondary ports in Portugal as well as locations such as Angola, Cape Verde, Guinea-Bissau, and Mozambique; some maritime administrative limits; small-scale bathymetric lines; and a small-scale converted Electronic Navigation Chart (ENC) cell for continental Portugal and the Madeira and Azores archipelagos.

***Metadata***

Metadata fact sheets are essential for inventorying, locating, and assessing the quality of geospatial data. These documents, which contain information about why, when, and where data was originally collected, are valuable from both a scientific and economic standpoint because they enable data reuse. Metadata is produced for all data, products, and services provided by the IDAMAR SDI. In accordance with the Infrastructure for Spatial Information in Europe (INSPIRE), metadata complies with the ISO 19115 standard. The metadata search engine was created to aid public access to the data.

***Specialized human resources***

Expertise in systems analysis, database systems administration, GIS, and Web programming was required for this project. Most contributors to the project have backgrounds in geography or earth sciences as well as master's degrees in various information technologies. This staff has developed the SDI and worked on ad hoc projects.

***Outreach***

Because some geospatial analysis tasks should only be performed by scientists, courses that range from three to five days were developed to introduce scientists to GIS concepts and software. These courses are tailored to the needs of scientists and

*Continued on page 20*

# A Geospatial Foundation

*Continued from page 19*

help spread GIS knowledge throughout the organization's scientific community while also providing tools that enable scientists to use GIS independently. This has allowed the organization's specialized staff time to work on both the SDI and advanced information projects.

### *Software*

The IDAMAR SDI relies on Microsoft for its operating system, Oracle for DBMS, and ESRI's ArcGIS for its GIS software. Specifically, the IDAMAR SDI makes use of ArcSDE, ArcIMS, and ArcGIS Server applications as well as single use and floating licenses for ArcView; ArcEditor; and the ArcGIS Spatial Analyst, ArcGIS 3D Analyst, ArcGIS Publisher, and ArcGIS Geostatistical Analyst extensions.

### *Hardware*

The SDI is supported by four servers—two internal and two external. A variety of IHPT devices (PDAs, laptops, PCs, workstations, printers, plotters, and high-resolution scanners) are used for some SDI functions.

### *Internal processes*

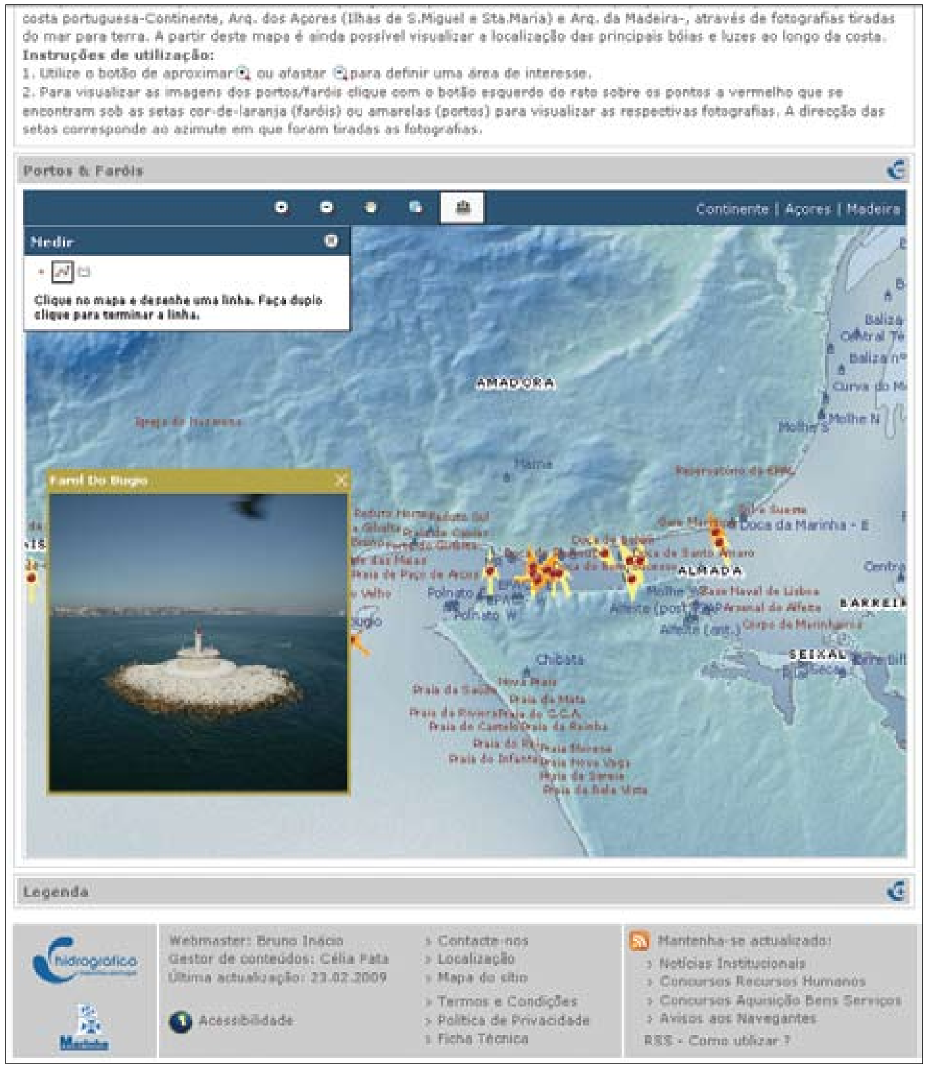
Implementing the SDI reengineered some IHPT production processes and introduced new ones. Setting up rules and workflows was necessary because making internal production more efficient was a main objective of the project.

### *Offline products*

Generated in response to ad hoc requests for information, offline products are normally distributed as CDs or DVDs. Although not necessarily related to the internal products generated by IHPT, the SDI answers specific information needs, and offline operations are advantageous from a naval security standpoint. In addition, some paper products are still used for a variety of purposes including thematic cartography. In the last three years, more than 30 ad hoc GIS projects based on the SDI have been developed.

### *Online products and services*

Online products and services provide broad access to the SDI. They are the most visible part of the public system that includes data catalogs, information products, and data services. Two Web portals (one internal and one external) allow users to obtain information products and services and provide the front end for data catalogs, data visualization applications, the metadata search engine, download services, and data services.




*As an aid for navigators, photographs of landmarks along the Portuguese coastline are available from the public Web site. This picture shows the lighthouse at the entrance to the Lisbon harbor.*

## Information Products

Some information products are available from one or both of the Web portals, while others are furnished offline. The scope of products supplied depends on use and encompasses public services, commercial services, environmental protection, naval missions, and research and development. The list of products included here is not exhaustive, only representative.

### *Exploring data with online data catalogs, data visualization, and metadata*

Several data catalogs allow users to explore data in IDAMAR SDI databases. Geographic interfaces assist in visualizing data such as horizontal control points, chart folios coverage, hydrographic surveys coverage, hydrographic soundings, sea bottom sediment samples, chemical analysis for water and sea bottom samples, tide observations, and sea state buoy observations.

The ENC World Catalog is one of the most relevant catalogs available. Although not entirely related to IHPT (because its geographic extent is the world), this catalog helps sea navigators identify the available cells relevant to their route. The coverage data, collected by the International Centre for ENCs (IC-ENC), is available at websig.hidrografico.pt/website/icenc and is updated monthly.

Information on the appearance of the coastline as it appears from the sea is very useful for sea navigation. A compilation of visual aids to the navigation of the Portuguese coastline is available from a customized ArcGIS Server Web site. This site provides links to photographs of coastline landmarks that help inexperienced sailors learn to recognize coast features.

Mission impact diagrams, which display anticipated environmental impacts by military activities, are important to mission planning. Assessing impacts by using only a table was very time consuming and could be confusing. Since 2006, IHPT has been supporting the navy and national military joint staff with geospatially based, color-coded mission impact diagrams. This product, which is used on a daily basis, provides an exhaustive and efficient interface that shows factors relevant for a specific point of interest.

Supporting marine research and development is another major objective for the IDAMAR SDI. Several information products have been developed that help scientists perform integrated analysis for a variety of marine disciplines, plan fieldwork, and communicate research results to the public. The Hotspot Ecosystem Research on the Margins of European Seas (HERMES) project is a perfect example of this type of support. More than 50 European partners are working on this project in seven different areas of the European shelf. A project GIS has been set up for each region to share data, coordinate fieldwork, and present results.

Geospatial metadata has long been recognized as critical to the full utilization of SDIs by users and administrators. Three key aspects of metadata are data inventory, data search, and data quality. There are other aspects related to metadata that are valuable, but these are the major ones for the IDAMAR SDI.

For an organization with environmentally based processes, maintaining a geospatial data inventory is fundamental. Gathering environmental data, especially marine data, can be very expensive. Performing the same measurement twice is a waste of time, money, and human resources, to say nothing of the cost of delays in acquiring necessary information. Currently available sampling methods (e.g., sensors, platforms) do not yet supply data sufficient to completely learn how the ocean works, so needless redundant sampling is a serious problem.

Geospatial metadata search mechanisms are more complex than traditional, text-based methods because these methods require dealing with multidimensional (i.e., spatial and attribute) data. Geospatial fact sheets allow fast and objective searches for data of interest. As geospatial databases increase to terabytes in size, metadata becomes even more important.

Data quality documentation is necessary to ensure that data can be reused in research and applications. Documentation prevents the use of data with inappropriate quality parameters that would adversely affect the quality of output and the decisions based on that output.

### *Accessing data through RSS*

In addition to traditional geographic interfaces for accessing data, the IDAMAR SDI also provides access to some technical and scientific data via Really Simple Syndication (RSS). This protocol is useful for accessing data through low bandwidth connections or devices such as PDAs or cell phones. Tide predictions for the current date and the next three days, as well as near real-time data from sea state buoys located off the shore of continental Portugal and Madeira Island (updated every two hours), are disseminated using RSS. Navigation warnings are also issued via RSS. All links to this data are compiled at www.hidrografico.pt/rss.php, and only an RSS reader is required to obtain this data.

### *Ad hoc independent projects*

Many projects developed from the IDAMAR SDI have been distributed via CD and DVD. ArcReader is used to explore the information supplied for these projects. Applications have been developed that address maritime safety; assist police investigations; support the numerous activities of the navy; and inform ship sinking crisis management and many other areas of public, commercial, and environmental protection service. Nearshore drift modeling, wave energy systems location, aquaculture structures location, and historical cartography are examples of applications under development.

## Future Work

The IDAMAR SDI is a valuable asset that supports its main mission objectives: ensuring safe sea navigation, supporting the navy's activities, protecting the environment, and contributing to knowledge of the ocean.

Ongoing data acquisition activities include converting historical analog data and products to digital format and registering this data in the system. A geospatial portal for better visualization is also being developed. Future enhancements include the implementation of GeoRSS feeds for the dissemination of technical and scientific data and the development of multicriteria geospatial analysis for mission impact diagrams that will improve environmental tactical decisions.

For more information, contact

Miguel Bessa Pacheco
Head of Data Centre
Instituto Hidrografico, Portuguese Navy IHPT
E-mail: bessa.pacheco@hidrografico.pt

## Learn More

Visit www.esri.com/training to learn more about the instructor-led course *GIS Portal Toolkit.*

# Improving Regional Water Quality Assessment

## Geodatabase improves data management and analysis capabilities

*By Jon Becker, U.S. Environmental Protection Agency Region 4*

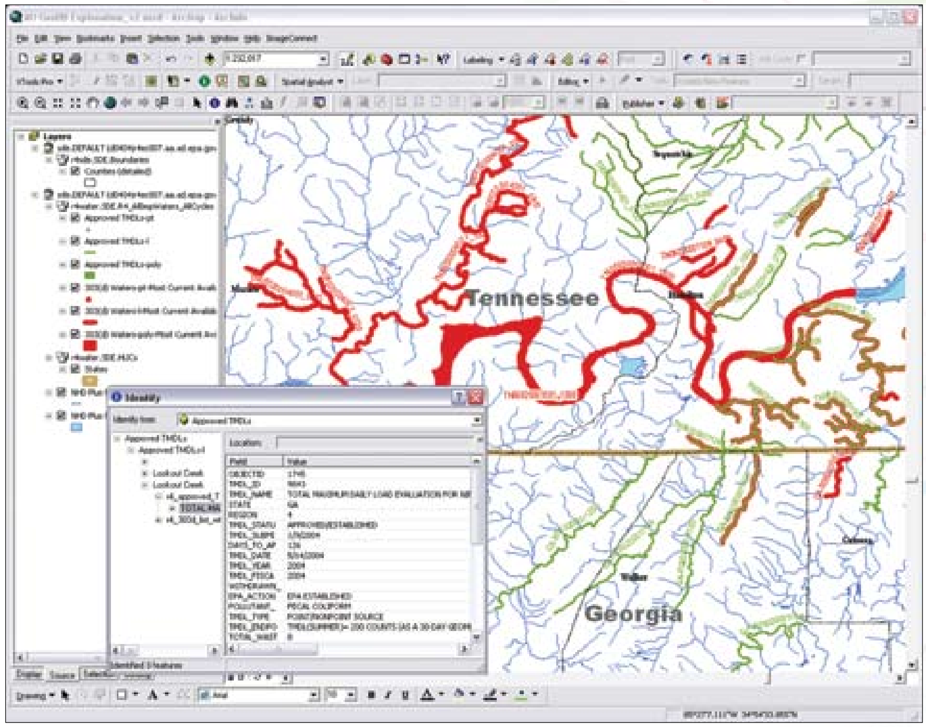
A geodatabase developed by the U.S. Environmental Protection Agency (EPA) Region 4 Water Management Division (WMD) manages georeferenced water quality assessment data from the region's eight southeastern states for various years far more efficiently than the previous system.

In accordance with the Clean Water Act, each state environmental agency tracks the status of water quality for water bodies located within its boundaries. Every even-numbered year, an assessment is made of each water body to determine whether it is meeting its designated uses. Each state agency tracks the status assessments in a local database and generates GIS datasets that depict the locations of these water bodies. Each lake, estuary, or river reach is called an assessment unit (AU) and assigned a unique identifier. While the EPA suggests recommended formats for assessment data and complementary GIS data, states often deviate somewhat from these formats to meet local needs.

Eight southeastern states submit assessment data and GIS files to EPA Region 4. These files are then forwarded on to EPA national headquarters for eventual input into the national Assessment and TMDL Tracking and Implementation System (ATTAINS). *[The Total Maximum Daily Load (TMDL) program determines the safe level of loading for a pollutant.]* The GIS files are addressed by river reach to the 1:100,000-scale National Hydrography Dataset (NHD) and incorporated into EPA's Watershed Assessment, Tracking and Environmental Results System (WATERS). This system integrates various EPA water-related databases via reach-addresses of the NHD.

Over the years, the staff of EPA Region 4 have obtained numerous assessment databases and GIS datasets from its eight southeastern states that were furnished in assorted and incompatible shapefiles, tables, and Microsoft Access databases. Using these datasets to analyze water body status for more than one state or year was difficult and time consuming even for experienced GIS users.

In 2007, EPA Region 4 staff explored the possibility of using a geodatabase to better manage water quality assessment data. Although




*Users can use the Identify tool to click on a feature and view records about those features stored in related tables or activate the hyperlink to the EPA database record for the feature.*

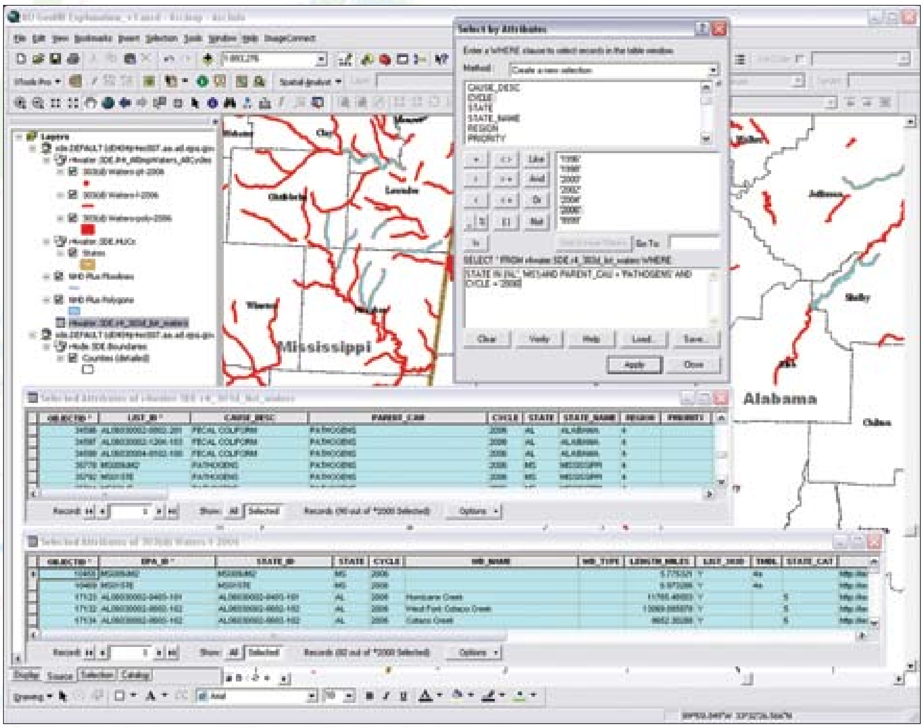
data is eventually reformatted by contractors at EPA headquarters into consistent formats for inclusion in ATTAINS and WATERS, the obvious roadblock in creating a geodatabase for Region 4 was the variety of assessment data formats and GIS data used by the states.

Region 4 contracted with Research Triangle Institute to develop a prototype geodatabase and populate it with reach-addressed versions of the states' assessment datasets. Region 4 staff then generated tables detailing the status of each AU from ATTAINS (then called the National Total Maximum Daily Load Tracking System). Relationship classes were created to relate the point, line, and polygon AU features to the assessment status tables using the AU identifier field. This was a one-to-many relationship because the AU is sometimes listed multiple times in the assessment status table if it has been tracked for several cycles and/or multiple water quality standard impairments (e.g., failures to meet swimming designated use because of high levels of pathogens).

Although this geodatabase format functioned fine, Region 4 staff soon realized it might be advantageous to populate it with the original state of GIS shapefiles rather than reach-addressed versions. While many states use NHD as the basis for their assessment units, some have reasons for not doing this.

For example, because Florida has mostly flat topography, and complex, highly modified hydrography is not well depicted at the NHD 1:100,000 scale, the Florida Department of Environmental Protection prefers to use its own water body identifiers (WBIDs) that depict small contributing drainage areas. If Region 4 staff are reviewing assessment data for Florida in a GIS, it is helpful to be able to view and use WBIDs instead of a reach-addressed approximation of those features.

However, Region 4 recognizes the value of having all state assessment GIS data in a consistent NHD-based format and continues




*Complex queries may be made in the detailed tables, then the relationships to the point, line, and polygon feature classes may be activated to display the locations of the results.*

encouraging states to adopt the NHD format as the framework for AUs. Some states, such as Florida, are exploring using a higher-resolution version of NHD to meet this need.

Because the region wanted to populate the geodatabase with GIS features from the states, the tables from each state GIS dataset had to be reformatted to a consistent format. The essential component for each AU record was an AU identifier because it was used to relate back to the ATTAINS tables. Features were also dissolved by the AU identifier so that there was only one feature per AU. Water body name and type fields for the AU were populated if the information was readily available in the state GIS dataset. A hyperlink field provides a link to the EPA Web page describing that water body. Length in miles was calculated for linear features and area in acres for polygon features.

The assessment data feature classes, tables, and relationship classes have been loaded into the ArcSDE server for Region 4. This provides a stable, fast-drawing platform. Having all state data and cycles in one feature dataset allows staff at the region to build various layer files pointing to these feature classes, which are just different definition queries. A layer depicting locations of approved TMDLs was also developed. Using the Identify button in ArcMap or ArcReader, a user can click on an impaired water body and see its impairments for all cycles and see the TMDLs that have been established for it. The built-in relationships give users the ability to query 303(d) listings or approved TMDLs by certain parameters, such as all pathogen-impaired waters, and activate the relationship classes to display those features in the GIS. *[A 303(d) listing identifies those lakes, wetlands, streams, rivers, and portions of rivers that do not meet all water quality standards for that state.]*

The geodatabase relationships between various assessment unit features and detailed tables provide WMD GIS staff with powerful and versatile analytic capabilities. By integrating disparate data formats from different states into a common structure, the geodatabase makes multiyear, multiple-state spatial analysis much easier than before. Answers to complex management requests or environmental progress reports can be generated in far less time than when georeferencing was contained in unmatched shapefiles.

Now new GIS data files are modified to fit the table format and loaded into the appropriate feature class. The tables from ATTAINS with the water body assessment status are periodically updated. Serving the data via ArcSDE also gives the region the ability to include these layers in ArcReader projects or other applications.

Although the Region has made great progress in managing its assessment GIS data, there is still much work to be done verifying the quality of the data and populating the ATTAINS database with assessment decisions. New organizational restructuring and procedures should help address these issues.

Reformatting the historical GIS files into this new consistent tabular framework involved a lot of work, but the resulting product has proved well worth the effort. GIS users can perform complex queries in related tables and activate the related features or simply use the Identify tool, click on AU features, and see the related tabular information. Relationship classes linking the ATTAINS tables of impaired waters and approved TMDLs have created a much more powerful and versatile analytic dataset that can generate useful information in a fraction of the time previously required.

For more information, contact Jon Becker of U.S. EPA Region 4, Watershed Management Division, at becker.jon@epa.gov.

## About the Author

Jon Becker is an environmental protection specialist in the Water Quality Analysis Branch of U.S. EPA Region 4 in Atlanta, Georgia. He obtained a master's degree in applied geography in environmental and resource studies from Texas State University.

*See the ESRI instructor-led course* Data Management in the Multiuser Geodatabase *for more information on this topic.*

# It's All about Context

## Remapping mammoth bone bed with ArcGIS

*By Donald Anton Esker, the Mammoth Site of Hot Springs, South Dakota*

*The bone bed at the Mammoth Site is 150 feet long by 75 feet wide and 67 feet deep.*

Scientists at a South Dakota research center are remapping the location of bones of Ice Age mammoths with GIS to preserve the context of the find and allow for the automation of quantitative analyses.

The Mammoth Site of Hot Springs, South Dakota, is an indoor, in situ Pleistocene bone bed that contains the remains of at least 56 mammoths and numerous other Ice Age animals. Approximately 26,000 years ago, the bone bed was the site of a steep-sided warm-water sinkhole pond. The warm water and year-round vegetation along the edges attracted mammoths, but once in the pond, the steep sides prevented their escape. Although entrapment was probably a rare event, the sinkhole was active as a trap for 300 to 700 years, which accounts for the large number of remains.

*The Trimble 5600 robotic transit being mounted to its tripod*

The site was discovered in 1974 during excavation for a housing development. Three mammoths were found during the first season. From the beginning, site mapping was a high priority. Mapping shows the location of each bone and records information about where it was found. By studying the bone bed's taphonomy *[i.e., studying what happened to an organism between the time of its death and the time it was excavated],* researchers can determine the environment of deposition and gain a clearer insight into the world of the mammoths.

### Early Mapping Methods

Initially, the Mammoth Site used a string grid to map the bone bed, and the cartography was entirely hand drawn. However, finding bones using one of these maps was like a treasure hunt. Most important, any quantitative analysis of a hand-drawn map also had to be done by hand.

Early efforts to computerize the mapping process using CAD software and a Nikon laser transit met with mixed success. The software was not well suited to mapping, and the Nikon transit proved difficult to use in the bone bed. The resulting map permitted automated cataloging of the bone bed but was less accurate and less detailed than the old string-grid system.

### Enter ArcGIS

The Mammoth Site recently embarked on a project to completely remap the bone bed using the latest technology. The center upgraded the GIS software to ArcGIS 9.2, bought a Trimble robotic transit, and improved site photography. These upgrades vastly improved map quality and opened the doors to hitherto impossible research.

The Mammoth Site employs a complex photographic mapping process that starts with anchor points. These are actually four or more metal washers that are placed around a bone before it is mapped. Larger bones require more washers. The washers appear in each photograph, and the Trimble transit is used to shoot in the precise coordinates of each washer.

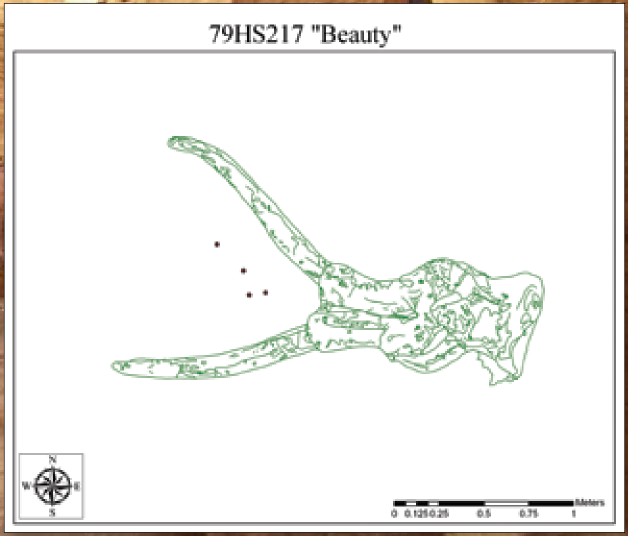
### Photos for Mapping and Documentation

While researchers use photographs to document the bones, photographs are also integral to the mapping process. Because the outline of the bone becomes part of the map, the photograph of the bone should be taken from directly above the bone on a level plane to avoid distortion.

Good photographs of smaller bones can be made with a bubble level on the camera, but mammoth bones, such as a femur or skull, cannot be fit in a single picture taken from ground level. Photo-stitching software helps but invariably introduces distortion because of the changes in camera perspective. The best solution is to take the picture from well above ground level.

Fortunately, the building enclosing the bone bed contains a remote-controlled crane that is used for bone and sediment removal and also serves as a mobile high-altitude digital camera mount. It is remotely controlled from a Panasonic CF-30 Toughbook laptop via a USB connection.


*A photograph of Columbian mammoth skull 79HS217, informally known as Beauty because of its excellent state of preservation*




*The digitized form of Beauty*


*The map image of Beauty superimposed on the original photograph used to create it.*

Once pictures have been taken, it is time to use the Trimble 5600 Robotic Total Station for Surveying to collect coordinate information. The bone itself is never touched. The anchor points (washers) that were placed around the bone are shot and the coordinates stored in the Trimble's memory.

## Making a Perfect Map

The photograph of the bone is adjusted to scale and printed so it can be manually digitized. Touching the digitizer's pen tip to each of the anchor points in the photograph determines the digitizer coordinates for each anchor point.

The coordinates captured by the Trimble for the anchor points are assigned to the anchor points digitized in ArcMap. A polyline shapefile is created in ArcCatalog with the same bone bed number as

*Continued on page 26*

# It's All about Context

*Continued from page 25*

the specimen being mapped. Next, the shapefile is opened for editing in ArcMap. By tracing over the bone with the digitizer pen, an accurate rendering of the bone appears in the appropriate place on the map.

The tracing is checked using Adobe Photoshop. The map is overlaid on the bone photograph. The individual polylines that make up the shapefile are merged, and the shapefile is appended to the Remap08 layer of the map.

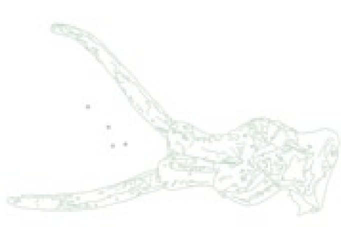
Next, the layer is opened for editing. The ancillary data collected about the bone during excavation is then added. Descriptive information, such as taxon, skeletal element, and completeness, is recorded as well as spatial information (e.g., elevation, azimuth, and inclination). The program even records the name of the discoverer and comments made about the bone during excavation. There are 30 fields in the attribute table for Remap08.

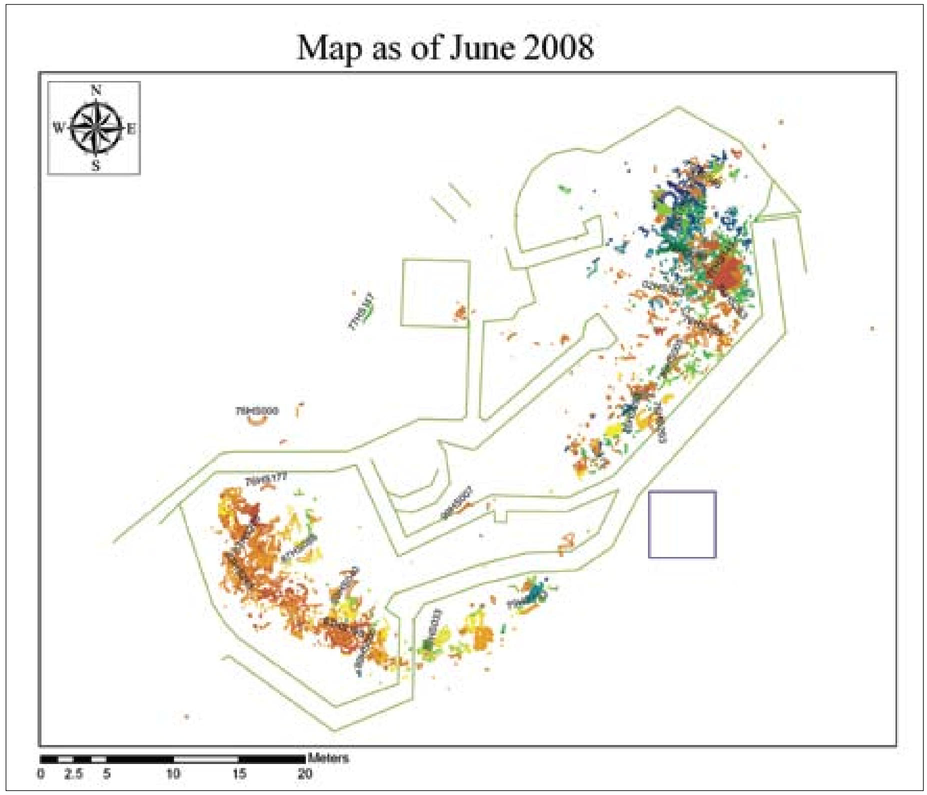
This information lets researchers parse the data in many different ways for easier analysis of questions such as

- Do certain taxa tend to collect in certain areas of the bone bed?
- Do certain elements tend to come to rest in particular orientations?
- Does the preservation degrade with proximity to the surface?

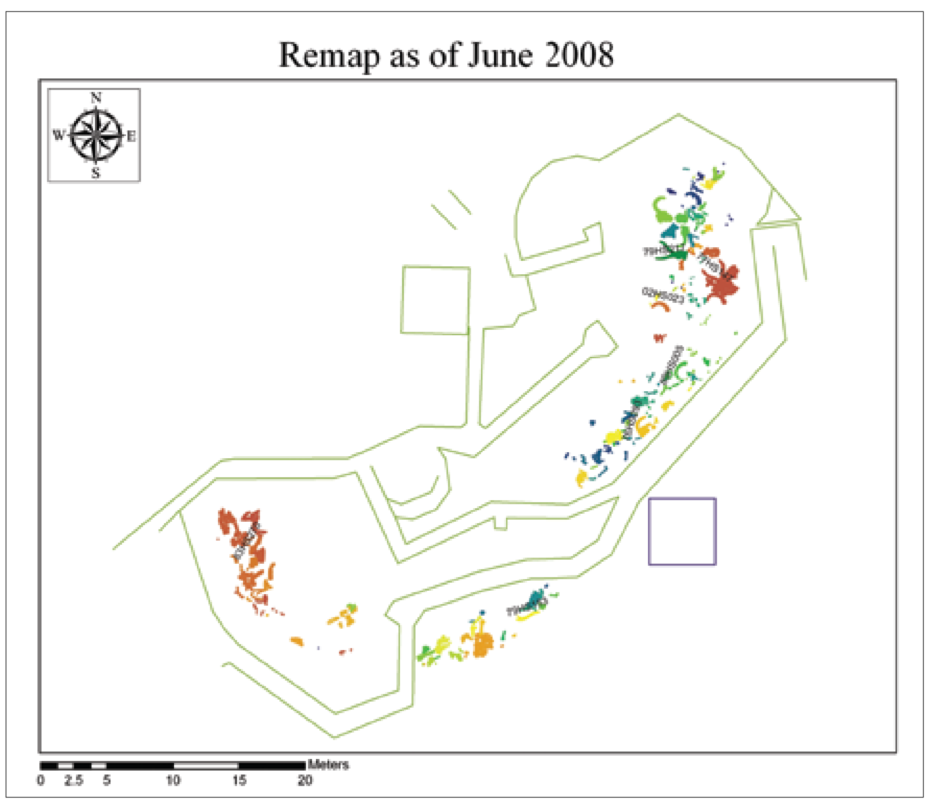
These questions may be answered when the remap project has been completed. For more information, contact

Donald Anton Esker
In Situ Bone Bed Curator
The Mammoth Site
of Hot Springs, South Dakota
Hot Springs, South Dakota
E-mail: done@mammothsite.org

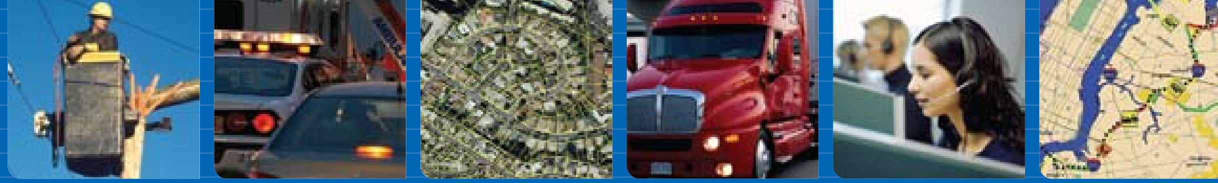





*The map showing all the bones excavated since 1974. The level of detail for bones mapped before 2007 is lower in this map.*




*The map showing all bones remapped since the project started in 2007. The level of detail for bones is higher in this map, but the map is not complete.*



NAVTEQ®

navteq.com/innovation

# Innovation. Inspiration. Reliability.

## Imagine finding it all with one map.

Businesses depend on NAVTEQ and ESRI for comprehensive mapping solutions. Both companies have a long-time alliance, collaborating on the delivery of high-value GIS and routing solutions. Working together, NAVTEQ and ESRI provide their customers with the flexibility required to quickly deploy and leverage mapping solutions that meet specific business needs.

NAVTEQ® map data can be used in all ESRI® products, including:

- Desktop GIS – ArcInfo®, ArcEditor™, ArcView®, and ArcGIS® Desktop extensions
- Server GIS – ArcGIS Server and ArcIMS®
- Developer GIS – ESRI Developer Network and ArcGIS Engine
- Mobile GIS – ArcGIS Mobile, ArcPad®, and Mobile ArcGIS Desktop Systems
- Hosted GIS – ArcGIS Online
- Business GIS – ArcGIS Business Analyst, Business Analyst Online℠, and ArcLogistics™

As leaders in GIS, NAVTEQ and ESRI are fueling a new era of innovative thinking and invention.

ESRI Technology
CORPORATE ALLIANCE

To learn more visit
www.navteq-connections.com

# Modeling Small Areas Is a **Big Challenge**

## Using the solar radiation analysis tools in ArcGIS Spatial Analyst

*By Shengli Huang, NASA Ames Research Center, and Pinde Fu, ESRI*

Scientists at the National Aeronautics and Space Administration (NASA) Ames Research Center, the Yellowstone Ecological Research Center (YERC), the Creekside Center for Earth Observation (CCEO), and ESRI have created 30-meter solar and temperature distribution maps in mountainous Yellowstone National Forest using tools in the ArcGIS Spatial Analyst extension. These products support ecological management in Yellowstone, the first and most famous national park in the world.

*Viewsheds are used in conjunction with sun position and sky direction information to calculate solar radiation for each location. A viewshed is upward looking and hemispherical.*

### Solar Radiation and Surface Temperature

Solar radiation is the primary energy source that drives many of the earth's physical and biological processes. Understanding its importance to the landscape at a variety of scales is key to understanding a broad range of natural processes and human activities. For example, in Yellowstone during the winter months, populations of ungulates (e.g., bighorn sheep, elk, and mule deer) are more concentrated in locations that receive relatively high levels of solar radiation.

Over a large area, it may not be very difficult to model the received solar radiation when the topography and cloud cover are not considered. However, modeling the solar radiation received at locations in mountainous areas with complex topography at 30-meter resolution is not a simple task. The amount of radiation may vary spatially and temporally in complex ways that are difficult to measure. Because solar radiation data is not readily available, researchers usually base geostatistic and geointerpolation models on limited point data from weather stations to interpolate solar radiation and temperature. However, because these stations are sparsely distributed and located in open, flat, and populated areas, they are not spatially representative of the area.

### Looking at Solar Radiation Modeling

At landscape scales, topography is the major factor that determines the spatial variability of incoming solar radiation (insolation). Variation in elevation, orientation (i.e., slope and aspect), and the shadows cast by topographic features all affect the amount of solar radiation received at different locations. Measuring variability is also confounded by a site's latitude, the local cloud cover present when measurements are taken, and sun angle shift (changes attributable to differences in time of day and time of year). These factors contribute to the variability of microclimates and include factors such as the spatial distribution patterns of air and soil temperature, evapotranspiration, snow melt patterns, soil moisture, and the amount of light available for photosynthesis.

A team composed of researchers from NASA, YERC, CCEO, and ESRI, led by Dr. Chris Potter of NASA, has undertaken an ambitious research project that will model solar radiation and surface temperatures in Yellowstone and generate solar radiation and temperature data at 30-meter scales. This project makes use of high-resolution (30-meter vertically accurate) U.S. Geological Survey digital elevation model (DEM) data, Western Regional Climate Center (WRCC) observations, and Natural Resources Conservation Service SNOwpack TELemetry (SNOTEL) measurements.

With this large collection of data layers, the challenge is to model the solar radiation for each 30-meter pixel using a methodology that considers many spatial and temporal factors related to atmospheric conditions, site latitude, elevation, slope and aspect, daily and seasonal shifts in sun angle, and the effects of shadows cast by surrounding topography. The Solar Radiation toolset, which became available with the release of ArcGIS 9.2 Spatial Analyst, enables the team to efficiently implement time-consuming processing of this data in a timely fashion.

### Data Methodology

The solar radiation analysis tools available with the ArcGIS Spatial Analyst extension enable the team to map and analyze the effects of the sun over a geographic area for specific time periods. These tools account for atmospheric effects, site latitude and elevation, steepness (slope) and compass direction (aspect), sun angle shift, and topography shadows.

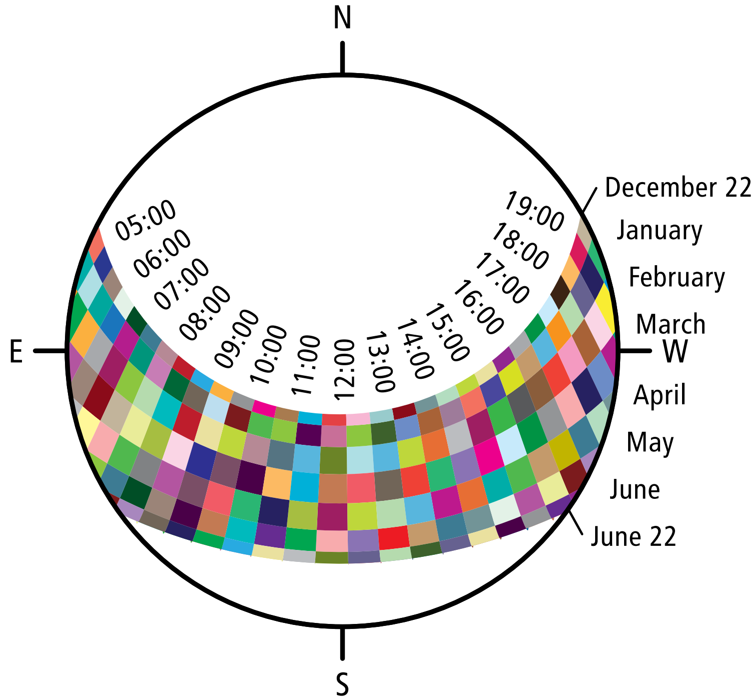
These calculations, which can be performed for point locations or entire geographic areas, are carried out using these four steps:

1. An upward-looking hemispherical viewshed is calculated based on topography.
2. The viewshed is overlaid on a direct sunmap to estimate direct radiation.
3. The viewshed is overlaid on a diffuse skymap to estimate diffuse radiation.
4. The process is repeated for every location of interest to produce an insolation map.

An upward-looking hemispherical viewshed for every location is calculated from the digital elevation model. A hemispherical viewshed looks like a fish-eye photograph and provides a view of the entire sky from ground level.

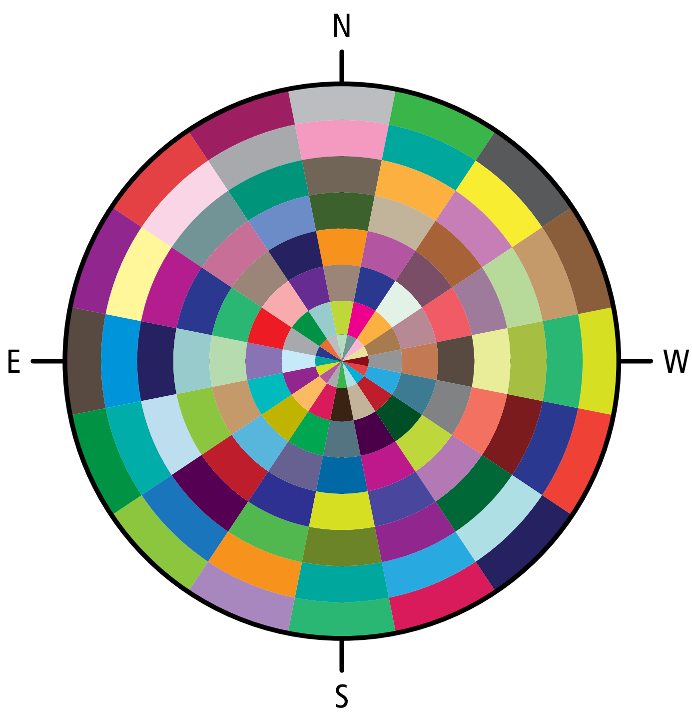
Direct insolation for a location is calculated using the viewshed and a sunmap of the study area. A sunmap is a raster representation that displays the sun track or apparent position of the sun as it varies through the hours of the day

*Continued on page 30*

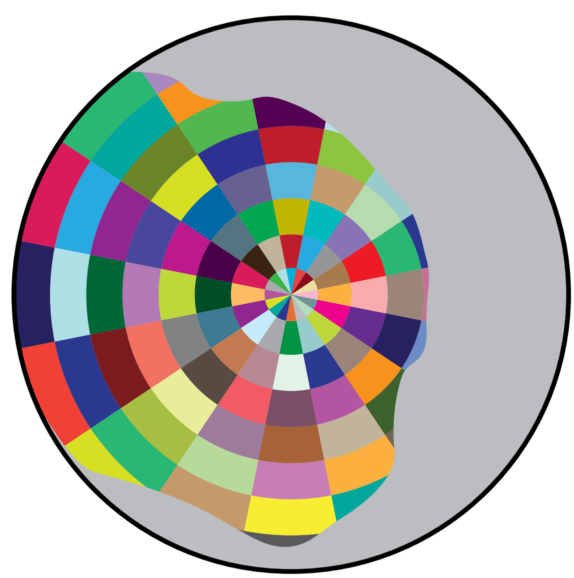



A sunmap for 45 degrees North latitude is calculated from the winter solstice (December 21) to summer solstice (June 21).

The sunmap is further overlaid with the calculated viewshed to calculate the direct solar radiation.




A skymap with sky sectors defined by 8 zenith divisions and 16 azimuth divisions. Each color represents a sky sector, or portion of the sky, from which diffuse radiation originates.



The sunmap is further overlaid with the calculated viewshed to calculate the direct solar radiation.

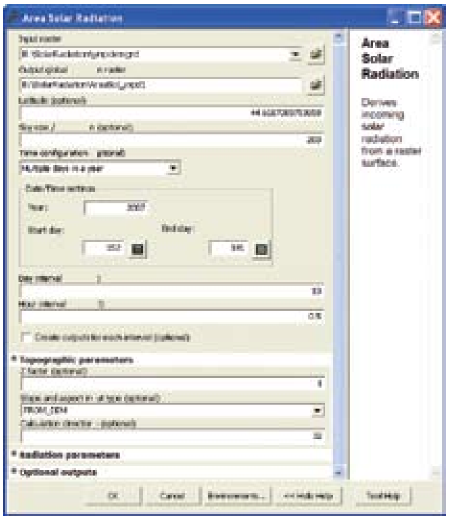
**For More Information**

Visit www.esri.com/training to learn more about these ESRI courses:

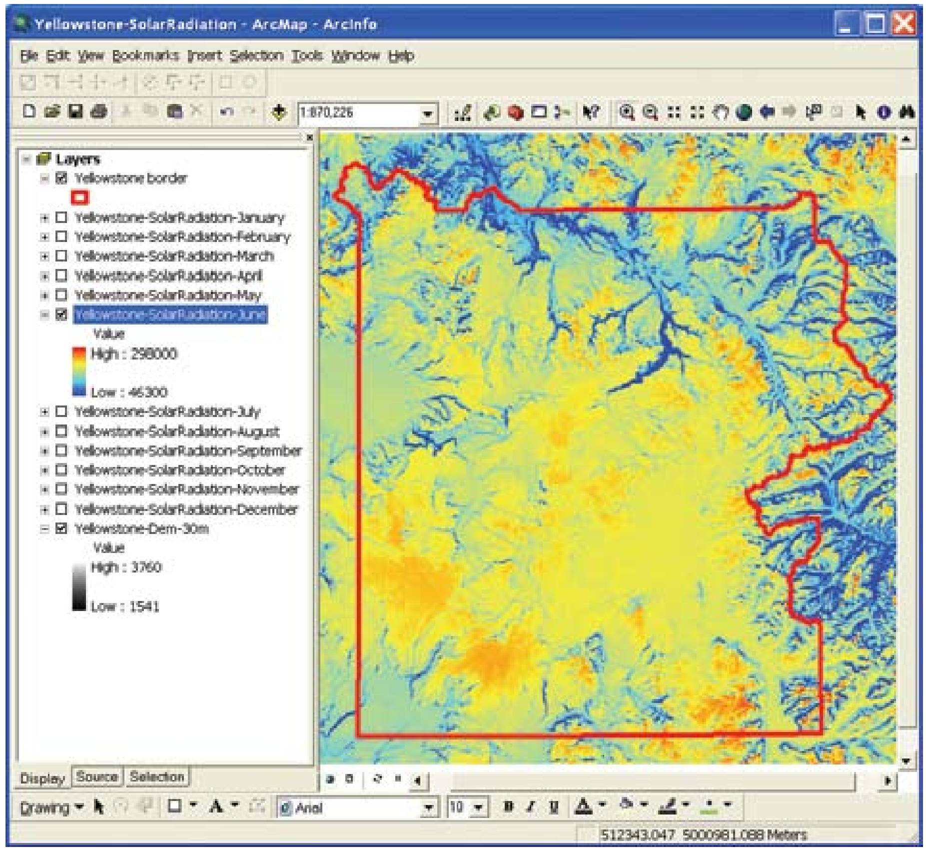
- *Learning ArcGIS Spatial Analyst,* a Web course
- *Working with ArcGIS Spatial Analyst,* an instructor-led course
- *Working with ArcGIS Spatial Analyst for Geospatial Intelligence,* an instructor-led course
- *Advanced Analysis with ArcGIS,* an instructor-led course

# Modeling Small Areas Is a **Big Challenge**

*Continued from page 28*




*Team members can quickly be productive because the solar radiation tool has been completely documented in ArcGIS.*




*Team members calculated 12-month solar radiation in Yellowstone.*

and through the days of the year, the same view one might see by looking up and watching the sun's position as it moves across the sky over time. It consists of discrete sectors defined by the sun's position at particular intervals during the day (hours) and time of year (days or months).

The sunmap is overlaid with the viewshed raster. The topographic shadow effect is accounted for by gap fraction. Gap fraction is the proportion of unobstructed sky area in each sector. Direct radiation is then calculated for each sunmap sector using a transmission model based on gap fraction, sun position, atmospheric attenuation, and ground receiving surface orientation. The sum of the radiation of all sectors is the total direct radiation this location receives.

Diffuse insolation for a location is calculated using its viewshed raster and a skymap of the study area. The skymap represents a hemispherical view of the entire sky divided into a series of sky sectors defined by zenith and azimuth angles. Each sector is assigned a unique identifier value along with the centroid zenith and azimuth angles. Diffuse radiation is then calculated for each sky sector based on direction (zenith and azimuth). The skymap is overlaid with the viewshed raster. As with the direct insolation, the topographic shadow effect is accounted for by gap fraction. Diffuse radiation is then calculated for each skymap sector using a uniform diffuse model or a standard overcast diffuse model. The sum of the radiation of all sectors is the total diffuse radiation this location receives.

Solar radiation for a ground location is calculated by summing the above direct and diffuse insolation originating from the unobstructed sky directions. The calculation is repeated for all locations of a selected area of a DEM to obtain an insolation map of the area. *[Reflected radiation contributes only a small proportion of total solar radiation (except for locations surrounded by highly reflective surfaces). The solar radiation tools in the ArcGIS Spatial Analyst extension do not include reflected radiation in total radiation calculations.]*

The solar radiation tools in ArcGIS, which provide many default and optional parameter inputs, enabled the team to select the best local optimal application. In addition to standard parameters, such as the slope and aspect derived from the ESRI DEM model, elevation, and latitude, the team calculated the diffuse proportion and transmissivity and incorporated this information into the solar radiation model. Twelve long-term monthly solar radiations were calculated. The team found that while monthly temperature is not highly correlated with the corresponding monthly solar radiation, it is highly correlated with a one-month-lag solar radiation. This knowledge enabled the calculation of a lag-corrected linear regression on surface temperature.

## Invaluable Information for Decision Support

Solar radiation and surface temperature modeling is computationally demanding and complicated to implement. The dataset at this high resolution could not be generated without the automated DEM and solar radiation tools available through the desktop GIS environment. However, the monthly solar radiation and surface temperature at a resolution of 30 meters greatly assist efforts to ecologically manage pine beetle outbreaks, predict invasive species incursions, and preserve wildlife species habitat in Yellowstone.

Dr. Robert Crabtree at YERC is leading two important projects in Yellowstone. Funded by NASA, the goal of the first project is to model the potential intrusion of invasive species of Canadian thistle and cheatgrass into Yellowstone National Park. These species replace native vegetation in the park and threaten wildlife that rely on native plants as a food source. Solar radiation and temperature are two important parameters for this model.

The goal of the second project, funded by the National Science Foundation, is to investigate the outbreak of mountain pine beetles *(Dendroctonus ponderosae Hopkins),* which has killed large numbers of trees in Northern America. Temperature is one of the important covariates in determining the development of pine beetles.

The species studied in both projects develop at landscape-level scales measured in tens, rather than hundreds, of meters. According to Crabtree, the available low-resolution 4-kilometer datasets available are not sufficient. However, the newly generated 30-meter resolution solar radiation and temperature information "is a fabulous dataset for these models."

While solar radiation affects many biological processes that influence the distribution of species and their habitat selection, this data seldom appears explicitly as a covariate in habitat studies. In winter, the grass is covered by deep snowpack. Because it is too hard for animals to uncover food, the ungulate species, especially bison, may migrate from park to unprotected areas where they are killed by local farmers. This migration is mostly determined by forage production and snow melting.

Jennifer Sheldon, YERC vice president and lead project scientist, is studying small mammals in Yellowstone. Dr. P. J. White, director of Yellowstone National Park, is responsible for the wildlife management policy in Yellowstone. Sheldon and White are now working with NASA to model the distribution of forage production and snow melting in Yellowstone using solar radiation and temperature datasets.

## Conclusion

The high resolution solar radiation and temperature datasets are important and previously unavailable data inputs for modeling biological processes in Yellowstone National Park.

## About the Authors

Shengli Huang, a postdoctoral research scientist with NASA Ames Research Center, is an ecologist who majored in geography and ecology. He has been using GIS and remote sensing tools to conduct research in Yellowstone for four years.

Pinde Fu, a project lead and senior developer with ESRI Applications Development Services, studied solar radiation modeling with his advisor, Dr. Paul Rich, during his doctoral studies. He and Rich developed the ESRI solar radiation calculation engine.

## For More Information

The Solar radiation tools are fully explained at the ESRI Web site (http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_the_Solar_Radiation_tools). For more specific algorithms and applications, see the following publications:

Fu, Pinde. A Geometric Solar Radiation Model with Applications in Landscape Ecology. Ph.D. Thesis, Department of Geography, University of Kansas. Lawrence, Kansas, 2000.

Fu, Pinde, and Paul M. Rich. "A Geometric Solar Radiation Model with Applications in Agriculture and Forestry," *Computers and Electronics in Agriculture* 37: 25–35. 2002.

Rich, Paul M., Ralph Dubayah, William A. Hetrick, and Shawn C. Saving. "Using Viewshed Models to Calculate Intercepted Solar Radiation: Applications in Ecology," *American Society for Photogrammetry and Remote Sensing Technical Papers,* 524–529. 1994.

Huang, Shengli, Paul M. Rich, Robert Crabtree, Christopher Potter, and Pinde Fu. "Modeling Near-Surface Air Temperature from Solar Radiation and Lapse Rate: Application over Complex Terrain in Yellowstone National Park, USA," *Physical Geography,* 29, no. 2: 158–178. 2008.


Illustration by Rick Grady, ESRI

# Speak the Same Language

## Making a compelling case for GIS to business executives

Now, more than before, obtaining funding for starting or expanding a GIS program requires that the GIS manager present a strong business case to stakeholders. For those who are more familiar with the language of technology and GIS, speaking the language of business can be intimidating. Keith Wishart helps GIS managers bridge the gap between the technical and financial sectors within organizations. Wishart, a business strategist at ESRI (UK) Ltd., is a well-known speaker and author in the GIS industry, notable for his work quantifying the financial benefits of GIS. Andy Coote and Wishart authored "Show Me the Money—Making the CEO Listen," winner of the 2007 Association for Geographic Information (AGI) Best Paper Award. Wishart has also published articles in the *Guardian* newspaper. In this interview with ESRI, Wishart addresses the subject of making the business case for GIS.

**ESRI:** A business case is defined as "a proposal used to determine the effects a project will have on an organization's profitability and includes a challenge, proposed solution, and analysis of risk-adjusted costs and benefits of that solution." What is distinctive about the business case for GIS?

**KW:** On the one hand—nothing. The same business case rules apply as they would elsewhere. That being said, rightly or wrongly, the benefits of GIS are often seen as soft and intangible, or GIS is seen as an enabler of a larger system. I don't view that as a problem and have been addressing these issues.

What is distinctive, and what we hear time and again as the biggest barrier to adoption of GIS projects, is the lack of awareness amongst senior managers about what the technology can do. Often those making the business case forget this and don't sell the very simple benefits that we (GIS experts) take for granted. There are answers to questions that can only be derived geographically. That does not mean you are writing a technical report; rather, you are speaking the business language of executives and explaining quantitative examples of the benefits of GIS.

Look at it this way, if you ran into an executive in the elevator, you should be able to clearly articulate what GIS is and its advantages to the organization in 30 seconds. CEOs will not buy into GIS because they think it's cool technology. They need to understand the benefit to the bottom line. Simple = good. Complex = bad.

**ESRI:** If an organization already has GIS, hasn't it already made the business case for GIS? Is making the business case necessary for every GIS project?

**KW:** I guess they've already made *a* business case, but given the current economic climate, traditional anecdotal benefits will no longer get the funding. In terms of the necessity of a business case, it depends on the strategy and the management of the organization. Ideally, GIS should be managed within a strategic framework with allocated budgets for various operational or project activities. In this setup, smaller-scale product implementations could well be delegated down to operational managers who can call off against their own budgets without the need for a full-blown business case.

**ESRI:** Which is more difficult, making a case for a totally new GIS implementation or adding to existing GIS infrastructure?

**KW:** I'm not sure there is a general rule—both bring specific challenges. With a new implementation, there is often a lot of selling to be done to make people aware of what the technology can do. When adding to an existing infrastructure, the range of technical approaches or options tends to increase, and sometimes this can create unnecessary complexity. If there have been failures with past GIS projects, articulating quantitative benefits becomes a greater necessity.

**ESRI:** Can organizations run an internal cost-benefit analysis, or do they need a consultant? How useful are the ROI *[return on investment]* calculators available on the Web?

"Rather than focusing on technical issues, the problem must be driven by the strategic objectives of the organization."

**KW:** It really depends. I'd like to think most organizations should be able to do it themselves, but there are going to be cases when external help is required. From my point of view, I think business case development should be a core skill for any organization, and there are significant benefits in having the business case developed by the same managers/users who will then go on to realize the benefits. I would also emphasize that the process is highly iterative.

In regard to ROI calculators, I think we are beginning to see a bit of a push-back on them. C-level *[e.g., CIO, CFO]* executives reject what they see as a painting by numbers approach. I think if you have a well-constructed, thoughtful business case and for some reason the ROI numbers don't stack up, you have more chance of going back through it and working out what the problem is than if you have a stellar ROI but the logic is missing.

**ESRI:** You found that the top concerns of senior executives include return on investment, aligning ICT *[information and communication technologies]* with business needs; integrating systems; and improving customer service, resource management, outsourcing, and security. Why is it important to think about what keeps executives awake at night?

**KW:** Because if you can help solve their problems, you'll get their time, support, and approval for funds. A CEO will not be worrying about the organization's GIS, if he even knows about it, but he might be worrying about cutting overtime costs on his vehicle fleet. We can then see a solution, such as using ArcLogistics, and present our "overtime cost reduction solution." Or a CEO might want to increase the productivity of field-workers. We can then see a solution with mobile GIS.

I devised the benefits spectrum *[illustrated in Figure 1]* because there are a lot of cost checklists about such things as project estimating templates and budget planners, but there was no equivalent benefit checklist. I basically thought, How can GIS improve the inputs and outputs to the process or the process itself? And what effects does this have on customers, cost savings, and so on? The main point of the checklist is to help the business case be focused on one or maybe two benefits—it's not the aim to deliver all the benefit types—otherwise, the message becomes blunted.

**ESRI:** What mistakes are usually made when creating the business case?

**KW:** I think the most common mistake is getting the process back to front. By that I mean that if you do a lot of analysis but only engage with senior stakeholders at the end of the process—when you think you have the "answer"—it tends not to fly. You need to spend a lot of time with senior stakeholders getting their buy-in, and sometimes the detailed analysis can follow.

**ESRI:** Please describe the three phases—analysis, evaluation, presentation—of the business case process.

**KW:** The first phase of the process is analysis, or defining a business problem, which is key to creating a successful business case. Rather than focusing on technical issues, the problem must be driven by the strategic objectives of the organization. Interviewing senior executives will help determine how GIS can reach business objectives.

*Continued on page 34*

# Speak the Same Language

*Continued from page 33*

During the next phase, evaluating the GIS project, it's imperative to perform a rigorous analysis of risk associated with the project. It is necessary to create a project timeline, analyze costs and benefits, and determine that the project is feasible. Establishing implementation and maintenance costs of the project is the easier part, but benefits, both short and long term, are more difficult to determine. The benefits spectrum is a good starting point, as is the organization's finance department.

The finance department can also explain the standard way that figures are presented to executives, which is the final phase of the project. In presenting the project, benefits covering quantitative tangibles, such as cost avoidance, and qualitative intangibles, such as environmental impacts, are both important. Different organizations tend to have varying approaches to the final product. My view is that the final business case should be a very short document or presentation, because all the hard work—detailed analysis, lobbying, etc.—has been done elsewhere. The real end product is the agreement to commission the project.

**ESRI:** Let's spend some time discussing benefits. What kind of returns are going to make executives buy in?

**KW:** It's very difficult to generalize, but there have been a number of studies into this. The trouble is that returns accrue over very different time spans in different industries, and the return varies with project risk and the organization's own financial policies. Many organizations have a predetermined hurdle rate that a business case must deliver. I'd use that as a starting point.

Although there is a focus on ROI, I think it's more about the spirit of the approach: quantifying costs versus benefits and showing the value of the GIS project. To be honest, it's just a normal procedure in most enterprise IT environments, and as GIS heads in that direction, it just has to do the same. The final report will include multiple financial performance metrics, such as NPV (net-present value), IRR (internal rate of return), discounted payback period, FCF (free cash flow), and ROI.

Make sure data is transparent, keep records of how you arrived at specific numbers, and present simply with no false accuracy.

**ESRI:** Since you believe the focus should be on quantitative tangible benefits, what is the importance of intangibles? And how are they measured?

**KW:** I've got a whole paper on that one! But I would say a few points. Firstly, *intangible* does not mean "cannot be measured," which is often a commonly accepted definition. Accountants have been measuring intangibles for centuries, for example, customer relationships, trademarks, and management skills. There is nothing that you can't put a useful measure on—if something is important to your business, then you must have detected it somehow. And if you detected it, it can be measured. I often hear users say, "Oh, the benefits of GIS are intangible," as if that's a showstopper for the business case. It's not. I'm not saying it's easy to get good measures of intangibles, but it can be done. The prism model of intangible benefits *[illustrated in Figure 1]* incorporates other more intangible, yet very relevant, areas of concern: political, social, and environmental benefits.

**ESRI:** Please discuss an example of an ROI analysis that showed the benefits of GIS.

**KW:** At ESRI (UK) we are working really hard at getting our customers to quantify the benefits that GIS delivers. This is really important. If we say GIS is going to save £100,000, we'd better show it. We always use our customers'/end users' numbers—we never derive them ourselves. We are now building a library of quantified benefit studies, and we use these as inputs into new business cases as evidence.

Recently, we looked at refuse vehicle routing for a local government organization in England. The business problem they had was simple: rising costs such as overtime labor costs, vehicle running costs, rising fuel prices. A number of local authorities had already used transport consultants to review their refuse vehicle routes, but this organization wanted to be more dynamic—they recognized that refuse levels varied significantly from month to month due to seasonal lifestyle choices and industries, particularly tourism. The outcome was the authority could tune the GIS system month by month and avoid unwanted situations like one crew finishing early while another went into overtime. Fuel and operational costs were also significantly reduced, and all this also helped the organization with its carbon reduction targets. Overall, the return was many, many times the costs; they estimate savings of £110,000 per year. Improved customer service has also been a result of more efficient refuse collection.

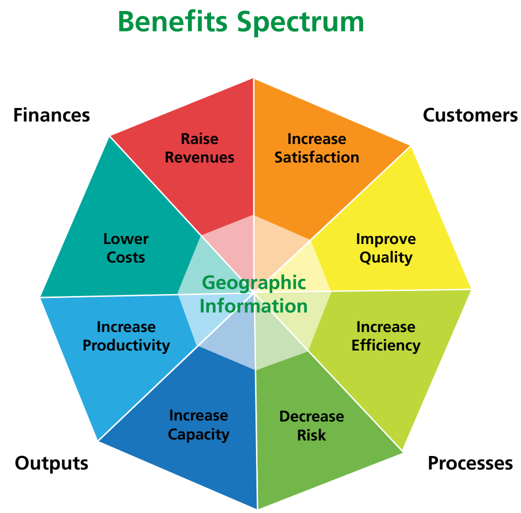



*Figure 1: Prism model of intangible benefits*

**Keith Wishart, ESRI (UK) Ltd.—Government Strategist**

In 2000, Keith Wishart joined ESRI (UK) as a consultancy program manager and is now part of the business strategy team. He is responsible for defining ESRI (UK)'s central government strategy and also plays a key role in corporate strategy developments. Wishart has held other roles including Internet services manager. As a business consulting manager, he worked with a range of industries: central and local government, defense, utilities, and the property and commercial sectors.

Before joining ESRI (UK), Wishart spent two years with TENET Technology as a business development manager. Prior to his employment with TENET, he was research fellow at University College London. He is also an active member of Intellect, the UK trade association for the technology industry, and a management team member of that organization's software and government groups. He holds an MBA from Cranfield School of Management in Bedfordshire, England, and a Ph.D. from the University of Sheffield, Sheffield, England.

### Just for Managers

ESRI offers two courses, *GIS for Managers,* a free Web training seminar, and *Planning for a GIS,* a Web course. Visit www.esri.com/training to learn more.

# The Most Important Part of a GIS

## Make sure staff have the right skills with a training plan

People are the key to a complete and successful GIS solution. It is vital to invest in training staff members, especially in this uncertain economy. As a wise manager once said, "One thing worse than training staff members and having them leave is not training them and having them stay."

Most organizations put a lot of time and effort into planning for GIS software and hardware acquisitions. However, the same effort is not always put into building a training plan. The best planned software and hardware solution will not achieve its full potential unless staff receive proper training at the right time. Unfortunately, training is sometimes a last-minute decision when end-of-budget-cycle money becomes available.

Having a training plan in place is a great way to define an organization's training needs and provide a means of reaching the ultimate GIS goals. A training plan is a living document that should be revisited on a regular basis. Its effectiveness should be evaluated by looking at job performance indicators. The process of building a training plan identifies and documents organizational knowledge and capabilities and the skills required to perform necessary GIS tasks. Comparing current knowledge and skills with required skills will identify any skills that should be acquired through training.

ESRI built an education team focused on helping make software users successful. Because not everyone learns in the same way, a variety of training formats are available.

"The biggest benefit from ESRI training is being able to learn from ESRI professionals. With ESRI training, you have fully qualified instructors who can answer most of your questions on the spot or are in the pipeline to get you answers if they aren't immediately known," said Steve Holmes, GIS manager for the City of Loveland, Colorado.

Once a training plan is complete, it can be included as a formal expenditure in the enterprise implementation. This will help ensure that money for training is available. After the training is complete, the training plan can be used to validate the investment as well as demonstrate the training effectiveness. Showing that training has improved staff GIS capabilities will help with the approval of future training.

Organizations can develop effective training plans with ESRI's training sales consultants. These consultants are available through regional offices to assist customers with their training needs. Nationwide, there are 11 training sales consultants with regional government and other industry-specific knowledge. Customers are paired with a consultant who focuses on their geography and industry. This assistance can be as simple as suggesting a class or as complex as creating an entire training plan for a large organization.

A powerful tool used by the consultant is the comprehensive training plan. This document outlines 12 GIS job roles common to many organizations and suggests instructor-led and Web-based training for each. This document can be used by organizations to build a training plan, or it can be used by the consultant to build a customized training plan.

When building a customized training plan, the consultant guides the organization through the planning process and helps identify GIS roles filled by staff members and the skills they will require. Once the skills and roles have been identified, the consultant can help perform a gap analysis by comparing staff skills and experience against the tasks that must be performed. Customers will rank tasks according to importance and time sensitivity. This will help ensure that the necessary training is prioritized and timed appropriately.

Once the consultant understands what customers want from GIS and identifies the most effective training solutions, the first iteration of an organization's training plan can be completed. A training plan will document the training necessary for each GIS-related job role or workflow, assist in budgeting and planning for training needs, and provide a long-term plan for growing the GIS skill set of an organization's staff members.

Training sales consultant assistance is offered by ESRI at no charge. More information on this service is available from an organization's ESRI account manager or regional office.

# Easy Access to Near Real-Time Data

## Looking at a methodology that generates aggregated live feeds for ArcGIS clients

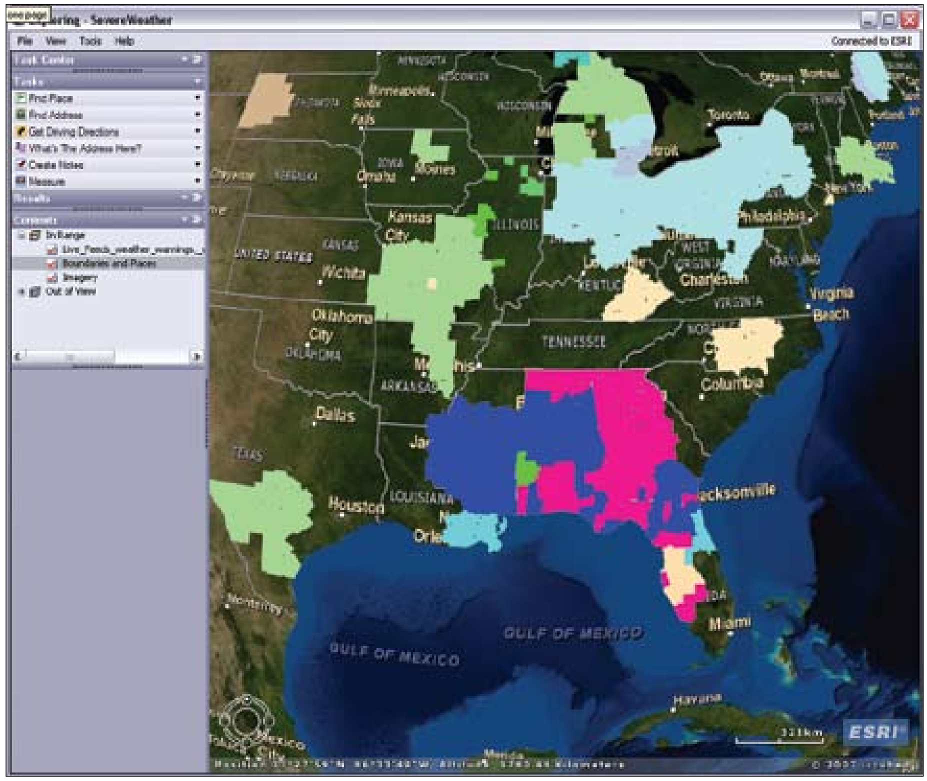
**ESRI** has developed a methodology that makes near real-time data and the results of analysis available through all ArcGIS clients. Called aggregated live feeds, this technique was developed by Derrick Burke and Paul Dodd of ESRI. It aggregates information captured from the Internet or Web sites; pushes that information into an ArcSDE database; and publishes this information through ArcGIS Server as a Web mapping service that can be accessed by ArcGIS Desktop, ArcGIS Server, and ArcGIS Explorer. Because these operations are performed on the server side, any client can use them without the need for custom code.

**Aggregated live feeds make near real-time data and the results of analysis available through all ArcGIS clients.**

Aggregated live feeds are used in applications ranging from homeland security to environmental analysis. For example, a lightweight browser application created for modeling contaminant leaks calls analysis capabilities from an ArcGIS Server geoprocessing service to perform plume modeling based on an aggregated ArcGIS Server service that contains the latest wind velocity and direction information. The analysis produces a plume that can be chained to other ArcGIS Server analyses such as identifying the demographics of the affected area.

This methodology uses simple batch scripting with a handful of public domain command line utilities to download and preprocess the feed data. The scripts use ArcSDE command line functions to push this data into the database. The scripts also incorporate logic that tracks the process to ensure they run as expected. If a load fails, an alert e-mail is sent to the administrator.

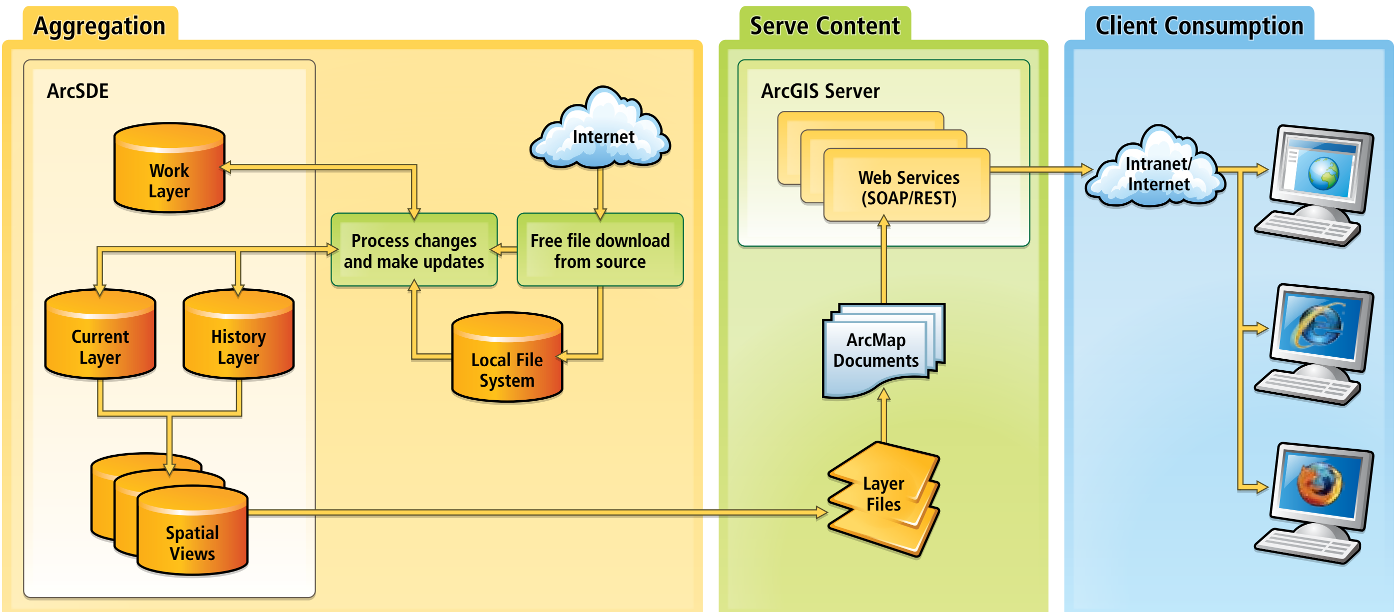
Scripts can run at varying intervals—every 5 minutes, every 30 minutes, once an hour, or once a day—depending on the application. This takes the load off clients. Continuously polling for fresh data can carry a heavy penalty, especially in browser-based applications. Processing feed data on the server side allows the client to poll for data only when needed, via standard ArcGIS Server protocols. Managing these feeds centrally can ease the demand on network resources by using a few systems




*Near real-time data, such as this severe weather warning information, can be made available to ArcGIS Explorer and other ArcGIS clients, without requiring custom coding, using aggregated live feeds.*

| Name | Description | URL |
|---|---|---|
| ASC2SDE | A tool that is part of the SE_TOOLKIT by Vince Angelo. This tool will load ASCII files (such as comma-separated values [CSV] files) into ArcSDE. | arcscripts.esri.com/details.asp?dbid=14767 |
| BLAT | A full featured command line e-mail tool used to send alerts when a load script fails. BLAT is also used in the Service Monitor. | www.blat.net/ |
| KML2SHP | A tool written by Srinivasa Rao that converts Google KML files to shapefiles. | arcscripts.esri.com/details.asp?dbid=14980 |
| sed | Stream Editor used to edit text files through the command line. | www.gnu.org/software/sed/ |
| WAIT | A command line tool that will wait for another process or a specific number of seconds. It is used to pause a script and monitor the ArcSDE sdemon–o status command through the Service Monitor. | dpotter.net/Technical/2007/09/utility-to-wait-for-a-process-waitexe/ |
| GNU Wget | A powerful HTTP, HTTPS, and FTP command line tool used to download data from the Internet. | www.gnu.org/software/wget/index.html#downloading |
| XML2CSV | Exports XML formatted content to a CSV file. | www.a7soft.com/xml2csv.html |

*Resources*




*An overview of the aggregated live feed methodology*

```
rem *****************
rem * Start process *
rem *****************

:Main

  echo. >>%log%
  echo Feed Update Started:%TIME% %DATE% >>%log%
  echo ------------------------------------------------ >%TempLog%
  echo.
  echo Starting '%feedtitle%' load routine
  echo ------------------------------------------------
  echo.

  call :SetWorkDir

  if not defined Abort (
    call :DownloadRoutine

    if not defined Abort (
      call :CheckArcSDE

      if not defined Abort (
        call :TruncateLayer

        for %%i in (%FileMask%) do (

          if not defined Abort (
            call :CheckShapefile "%%i"

            if not defined Skipped (
              call :ProcessFile "%%i"
            )
          )
        )
      )
    )
  )
```

*Figure 1: Sample code for shapefile loader*

to download feed content from the Internet, which avoids having many users requesting the same feed content. Clients can access these local services as operational layers or fuse them with other basemaps and operational content.

The current methodology can handle shapefiles from vendors such as DTN/Meteorlogix (www.dtnmeteorlogix.com); stream gauge information in a variety of spatial formats from the U.S. Geological Survey (USGS) at water.usgs.gov/waterwatch; and earthquake information in XML format (also from USGS) at earthquake.usgs.gov/eqcenter/catalogs/. It can use Internet sources such as Common Alerting Protocol (CAP/XML) content from the National Weather Service (www.weather.gov/alerts). CAP data is supplied in an open, nonproprietary standard data interchange format and provides details about weather and public safety warnings and alerts. Aggregated live feeds can also make use of raw ASCII, comma-separated values (CSV), and some custom formats. The application makes use of utilities that allow the scripts to handle decompressing files.

Once the data is pushed into ArcSDE, ArcGIS Server services are authored and served. Monitoring and notification on the availability of ArcGIS and ArcIMS services are furnished by ServiceMonitor, a Windows batch script developed by Dodd that uses DOS and a few off-the-shelf public domain utilities to monitor the availability of most

*Continued on page 38*

# Easy Access to Near Real-Time Data

*Continued from page 37*

Web sites or Web services. Using conditional logic capabilities, the script can be directed to restart services using logic provided by an administrator. ServiceMonitor checks Web Service Description Language (WSDL) and URLs to make sure that the site responds when it should. The new version also checks REST endpoints and ArcSDE. Service Monitor can be downloaded from ArcScripts at www.esri.com/arcscripts.

**This methodology data is designed to work with previous, current, and future releases of ESRI software.**

This methodology for providing near real-time data is designed to work with previous, current, and future releases of ESRI software. The approach developed by Burke and Dodd uses a variety of samples, scripts, batch files, and utilities. Many of these utilities and command line tools are available as native OS executables (either DOS or UNIX based). Aggregated live feeds developed by ESRI use a native DOS batch scripting, but UNIX command line, Python, or Perl could be used.

An additional back-office process employed is on-demand caching of services. See the articles "Strategies for on-demand caching" and "Updating your map caches automatically: The key to caching dynamic data" on the ArcGIS Server Blog at the ArcGIS Server Resource Center (resources.esri.com) for more information on this process.

ArcGIS developers and users have created tools that perform similar aggregated live feed functions. To implement aggregated live feeds, one should have a good understanding of ArcSDE and command line utilities, experience with ArcGIS Server, knowledge of DOS (or whatever scripting environment will be used), and a thorough understanding of the data that will be aggregated.

The sample script snippets in Figure 1 (a shapefile loader in this case) show how the commands are used to aggregate live feeds. The accompanying table lists and describes resources used to implement this methodology.

### About the Developers

Derrick Burke is the technology team lead in ESRI's Technical Marketing Department and has worked at ESRI for more than eight years. He was initially in Professional Services as a developer. Currently, he works in Technical Marketing creating prototypes using new technology and developing presentations.

Paul Dodd is the GIS systems administration team lead in the Technical Marketing Department. He has more than 25 years of experience in the computer industry working with mainframe, mini, and microcomputer systems and software. For more than 11 years at ESRI, he has worked with ArcSDE in conjunction with various Oracle and Microsoft database products and, over the years, has developed several popular data-loading and monitoring utilities for ArcSDE.

## Utility Aids Developers and ESRI

### Generate API usage statistics on dependencies, versions, and calls

.NET developers who are developing against ESRI application programming interfaces (APIs) now have a new utility that will help them gain a better understanding of the ESRI libraries and objects.

ESRI API Evaluator, published with ArcGIS 9.3, gathers information by scanning executable (.exe) or dynamic-link library (.dll) files for specific usage of .NET types released by ESRI. It scans ArcGIS .NET code and generates a complete set of API usage statistics that will reveal the DLL dependencies; version information; and the number of calls made to all ESRI assemblies, interfaces, and members.

There are two main aspects of the utility: the Scanning wizard for defining the scan and the Results Viewer window for visualizing the results. Rules can be defined to include or exclude specific folders from scanning. Automatic upload of results can be specified in the prescan summary screen.

The Results Viewer window shows a representation of the scan results and provides a breakdown of the .dll and .exe files that are using ESRI APIs. Drilling down into the results provides information on API usage right down to a count of ESRI methods that have been called. Results are also available as a zipped XML file.

Scan results can be uploaded to a Web service hosted by ESRI for further analysis. Evaluating developer utilization of the current APIs will help ESRI better understand the needs of its users. The count of method and property calls to ESRI APIs, a list of implemented ESRI base classes and interfaces, assembly names, and contact details (if supplied) are uploaded to ESRI. ESRI will use any results from the evaluator to inform the design of future products for GIS developers.

Obtain the ESRI API Evaluator from ArcScripts at www.esri.com/arcscripts. Microsoft .NET Framework Version 2.0 Redistributable Package is required for this tool.

# Answering *Why* Questions

## An introduction to using regression analysis with spatial data

*By Lauren Scott, ESRI Geoprocessing Spatial Statistics Product Engineer, and Monica Pratt,* ArcUser *Editor*

Regression analysis allows you to model, examine, and explore spatial relationships and can help explain the factors behind observed spatial patterns. Regression analysis is also used for prediction. Tools included in the Modeling Spatial Relationships toolset, found in ArcToolbox, help answer *why* questions such as

- Why are there places in the United States where people persistently die young? What might be causing this?
- Why do some places experience more crime or fire events? Can we model the characteristics of these places to help reduce these incidents?
- Why do some locations have a higher-than-expected rate of traffic accidents? Are there factors contributing to this? Are there policy implications or mitigating actions that might reduce traffic accidents across the city and/or in particular areas?

You may want to understand why people are persistently dying young in certain regions, for example, or predict rainfall where there are no rain gauges. The tools in this toolset include Ordinary Least Squares (OLS) Regression and Geographically Weighted Regression (GWR).

OLS, the best known of all regression techniques, is the proper starting point for all spatial regression analyses. It provides a global model of the variable or process you are trying to understand or predict (early death/rainfall) and creates a single regression equation to represent that process.

GWR is one of several spatial regression techniques increasingly used in geography and other disciplines. GWR provides a local model of the variable or process you are trying to understand/predict by fitting a regression equation to every feature in the dataset. When used properly, these methods are powerful and reliable statistics for examining/estimating linear relationships.

Linear relationships are either positive or negative. If you find that the number of search and rescue events increases when daytime temperatures rise, the relationship is said to be positive; there is a positive correlation. Another way to express this positive relationship is to say that search and rescue events decrease as daytime temperatures decrease.

Conversely, if you find that the number of crimes goes down as the number of police officers patrolling an area goes up, the relationship is said to be negative. You can also express this negative relationship by stating that the number of crimes increases as the number of patrolling officers decreases. The illustration at the top of the next page depicts both positive and negative relationships as well as the case where there is no relationship between two variables.

Correlation analyses and their associated graphics, depicted in this illustration, test the strength of the relationship between two variables. Regression analyses, on the other hand, make a stronger claim. These analyses attempt to demonstrate the degree to which one or more variables potentially promote positive or negative change in another variable.

### Using Regression Analysis

Regression analysis can be used for many types of applications such as modeling fire frequency to determine high-risk areas and better understand the factors that contribute to high-risk areas. It can be used to model property loss from fire as a function of variables such as degree of fire department involvement, response time, or property value. If you find that response time is the key factor, you may need to build more fire stations. If you find that involvement is the key factor, you may need to increase equipment/officers dispatched.

Regression analysis can help you better understand phenomena to make better decisions, predict values for phenomena at other locations or times, and test hypotheses.

Modeling a phenomenon can yield a better understanding that can affect policy or provide input for deciding which actions are most appropriate. The basic objective is to measure

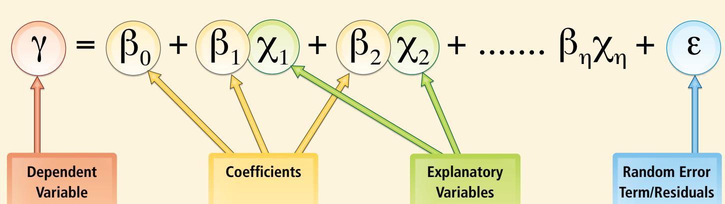
## Regression Analysis Components

### Terms and basic concepts

It is impossible to discuss regression analysis without first becoming familiar with a few of the terms and basic concepts specific to regression statistics.

**Regression equation** is the mathematical formula is applied to the explanatory variables to best predict the dependent variable you are trying to model. Although those in the geosciences think of X and Y as coordinates, the notation in regression equations uses *X* and *y*. The dependent variable is always *y*, and independent or explanatory variables are always *X*. Each independent variable is associated with a regression coefficient describing the strength and the sign of that variable's relationship to the dependent variable. A regression equation might look like the accompanying illustration where *y* is the dependent variable, the *X*s are the explanatory variables, and the βs are regression coefficients.

$$\gamma = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \ldots\ldots\ \beta_\eta\chi_\eta + \varepsilon$$

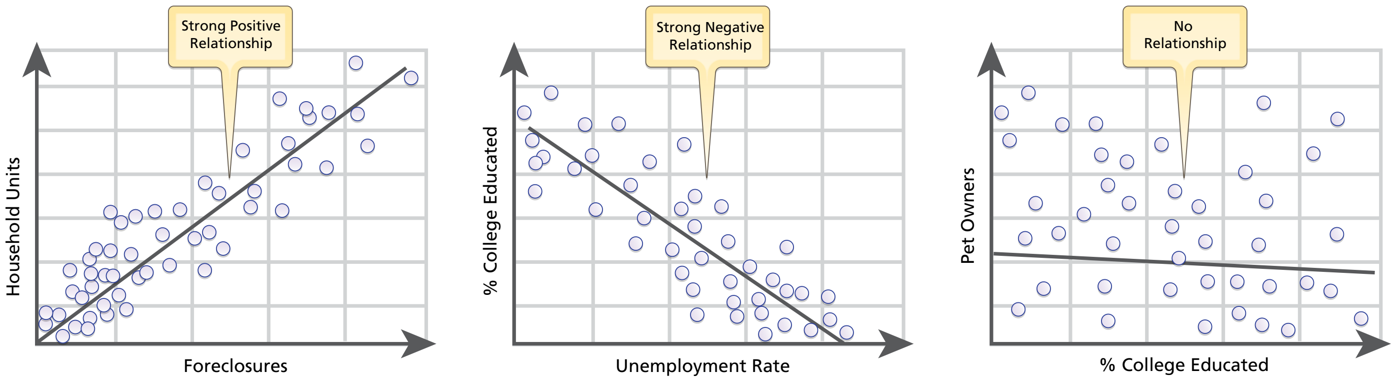



*Elements of an OLS regression equation*

Suppose you want to both model and predict residential burglary (RES_BURG) for the census tracts in your community. You've identified median income (MED_INC), the number of vandalism incidents (VAND), and the number of household units (HH_UNITS) to be key explanatory variables.

The equation would have the elements shown here:

RES_BURG = $\beta_0 + \beta_1$ * (MED_INC) + $\beta_2$ * (VAND) + $\beta_3$ * (HH_UNITS) + $\varepsilon$




*These graphs show relationships of two variables when that relationship is positive and negative as well as when no relationship is indicated.*

the extent that changes in one or more variables jointly affect changes in another. For example, understanding the key characteristics of the habitat of an endangered species of bird (e.g., precipitation, food sources, vegetation, or predators) may help design legislation that will more effectively protect that species.

Modeling a phenomenon to predict values for that phenomenon at other places or other times is another valid and valuable use of regression analysis. In this case, the basic objective is to build a prediction model that is consistent and accurate. You could use this model to predict rainfall in places (such as peaks or valleys) where there are no gauges, based on a set of variables that explain observed precipitation values. Regression may be used in cases where interpolation is not effective because of insufficient sampling.

You can also use regression analysis to test hypotheses. Suppose you are modeling residential crime to better understand it and implement policy to prevent it. At the outset, you probably have questions or hypotheses you want to test. Some of these might include

- Will there be a positive relationship between vandalism incidents and residential burglary (i.e., Broken Window Theory)?
- Is there a relationship between illegal drug use and burglary? Might drug addicts steal to support their habits?
- Are burglars predatory? Might there be more incidents in residential neighborhoods with higher proportions of elderly or female-headed households?
- Are people at greater risk for burglary if they live in a rich or a poor neighborhood?

Using regression analysis, you can explore these relationships to answer these questions.

Building a regression model is an iterative process that involves finding effective independent variables to explain the process

*Continued on page 42*

**Dependent variable *(y)*** is the variable representing the process you are trying to predict or understand (e.g., residential burglary, foreclosure, rainfall). In the regression equation, it appears on the left side of the equal sign. While you can use regression to predict the dependent variable, you always start with a set of known *y* values and use these to build (or to calibrate) the regression model. The known *y* values are often referred to as *observed values.*

**Independent/Explanatory variables *(X)*** are used to model or predict the dependent variable values. In the regression equation, they appear on the right side of the equal sign. We say that the dependent variable is a function of the independent (or explanatory) variables. If you are interested in predicting annual purchases for a proposed store, you might include in your model explanatory variables representing the number of potential customers, distance to competition, store visibility, and local spending patterns.

**Regression coefficients (β)** are computed by the regression tool. They are values, one for each explanatory variable, that represent the strength and type of relationship the explanatory variable has to the dependent variable. Suppose you are modeling fire frequency as a function of solar radiation, vegetation, precipitation, and aspect. You might expect a positive relationship between fire frequency and solar radiation (i.e., the more sun, the more frequent is occurence of fire incidents). When the relationship is positive, the sign for the associated coefficient is also positive. You might expect a negative relationship between fire frequency and precipitation (places with more rain have fewer fires). Coefficients for negative relationships have negative signs. When the relationship is a strong one, the coefficient is large. Weak relationships are associated with coefficients near zero. $\beta_0$ is the regression *intercept*. It represents the expected value for the dependent variable if all of the independent variables are zero.

*Continued on page 42*

# Answering *Why* Questions

*Continued from page 41*

you are trying to model/understand, running the regression tool to determine which variables are effective predictors, then removing/adding variables until you find the best model possible. The accompanying article, "Regression Analysis Components: An introduction to terms and basic concepts," defines the terms used when discussing this type of analysis.

## Regression Analysis Issues

OLS regression is a straightforward method that has both well-developed theory behind it and effective diagnostics to assist with interpretation and troubleshooting. OLS is only effective and reliable, however, if your data and regression model meet/satisfy all the assumptions inherently required by this method. Be sure to visit the ArcGIS Resource Center for ArcGIS Desktop (resources.esri.com/arcgisdesktop) and read "How Regression Models Go Bad." This article supplies an excellent discussion of this topic with examples.

Spatial data often violates the assumptions/requirements of OLS regression, so it is important to use regression tools in conjunction with appropriate diagnostic tools that can assess whether or not regression is an appropriate method for your analysis, the structure of the data, and the model being implemented.

## Spatial Regression

Spatial data exhibits two properties that make it difficult (but not impossible) to meet the assumptions and requirements of traditional (nonspatial) statistical methods such as OLS regression.

First, geographic features are more often than not spatially autocorrelated. This means that features near each other tend to be more similar than features that are farther away. This creates an overcount type of bias when using traditional (nonspatial) regression methods.

Second, geography *is* important. Often, the processes most important to the model are nonstationary; these processes behave differently in different parts of the study area. This characteristic of spatial data can be referred to as regional variation or spatial drift.

True spatial regression methods were developed to robustly deal with these two characteristics of spatial data and even incorporate the special qualities of spatial data to better model data relationships. Some spatial regression methods deal effectively with spatial autocorrelation, while others accommodate nonstationarity processes well. At present, no spatial regression methods are effective for both characteristics. However, for a properly specified GWR model, spatial autocorrelation is typically not a problem.

There seems to be a big difference between how a traditional statistician and a spatial statistician view spatial autocorrelation. The traditional statistician sees spatial autocorrelation as a bad thing that needs to be removed from the data (through resampling, for example) because it violates the underlying assumptions of many traditional (nonspatial) statistical methods.

For the geographer or GIS analyst, spatial autocorrelation is evidence of important underlying spatial processes at work. It is an integral component of the data. Removing space removes data from the spatial context—it is like getting only half the story. The spatial processes and spatial relationships evident in the data are a primary interest and are one of the reasons geographers get so excited about spatial data analysis.

However, to avoid an overcounting type of bias in your model, you must identify the full set of explanatory variables that will effectively capture the inherent spatial structure in your dependent variable. If you cannot identify all these variables, you will very likely see statistically significant spatial autocorrelation in the model residuals. Unfortunately, you cannot trust your regression results until this is remedied. Use the Spatial Autocorrelation tool in the Spatial Statistics toolbox to test for statistically significant spatial autocorrelation in your regression residuals.

There are at least three strategies for dealing with spatial autocorrelation in regression model residuals: resampling input variables, isolating spatial and nonspatial components, and incorporating spatial autocorrelation into the regression model.

- Resample until the input variables no longer exhibit statistically significant spatial autocorrelation. While this does not ensure the analysis is free of spatial autocorrelation problems, these problems are far less likely

# Regression Analysis Components

*Continued from page 41*

**P-values** are generated by a statistical test that is performed by most regression methods to compute a probability for the coefficients associated with each independent variable. The null hypothesis for this statistical test states that a coefficient is not significantly different from zero (in other words, for all intents and purposes, the coefficient is zero and the associated explanatory variable is not helping your model). Small p-values reflect small probabilities and suggest that the coefficient is, indeed, important to your model with a value that is significantly different from zero (the coefficient is ***not*** zero). For example, you would say that a coefficient with a p-value of 0.01 is statistically significant at the 99 percent confidence level; the associated variable is an effective predictor. Variables with coefficients near zero do not help predict or model the dependent variable; they are almost always removed from the regression equation unless there are strong theoretical reasons to keep them.

**$R^2$ / R-Squared** values, which range from 0 to 100 percent, are a measure of model performance. Multiple R-squared and Adjusted R-Squared are both statistics derived from the regression equation to quantify model performance. If your model fits the observed dependent variable values perfectly, R-Squared is 1.0 and you (no doubt) have made an error. Perhaps you've used a form of *y* to predict *y*. More likely, you will see R-Squared values such as 0.49, which you can interpret in the following manner: this model explains 49 percent of the variation in the dependent variable. To understand what the R-squared value is indicating, create a bar graph showing both the estimated and observed *y* values sorted by the estimated values. Notice how much overlap there is. This graphic provides a visual representation of how well the model's predicted values explain the variation in the observed dependent variable values. The Adjusted R-Squared value is always a bit lower than the Multiple R-Squared value because it reflects model complexity (the number of variables) as it relates to the data.

to occur when spatial autocorrelation is removed from the dependent and explanatory variables. This is the approach of a traditional statistician for dealing with spatial autocorrelation. It is only appropriate if spatial autocorrelation is the result of data redundancy (i.e., the sampling scheme is too fine).

- Isolate the spatial and nonspatial components of each input variable using a spatial filtering regression method. Space is removed from each variable, but then it is put back into the regression model as a new variable to account for spatial effects/spatial structure. Spatial filtering regression methods will be added to ArcGIS in a future release.
- Incorporate spatial autocorrelation into the regression model using spatial econometric regression methods. Econometric spatial regression methods will be added to ArcGIS in a future release.

## Regional Variation

Global models, such as OLS regression, create equations that best describe the overall data relationships in a study area. When those relationships are consistent across the study area, the OLS regression equation models those relationships well. However, when those relationships behave differently in different parts of the study area, the regression equation produces more of an average of the mix of relationships present. When those relationships represent two extremes, the global average will not model either extreme well.

When your explanatory variables exhibit nonstationary relationships (i.e., regional variation), global models tend to fall apart unless robust methods are used to compute regression results. Ideally, you will be able to identify a full set of explanatory variables to capture the regional variation inherent in your dependent variable. However, if you cannot identify all these spatial variables, you will again notice statistically significant spatial autocorrelation in your model residuals and/or lower-than-expected R-squared values. (R-squared values are a measure of model performance. Values vary from 0.0 to 1.0, with higher values being preferable.) Unfortunately, you cannot trust your regression results until this is remedied.

There are at least four ways to deal with regional variation in OLS regression models:

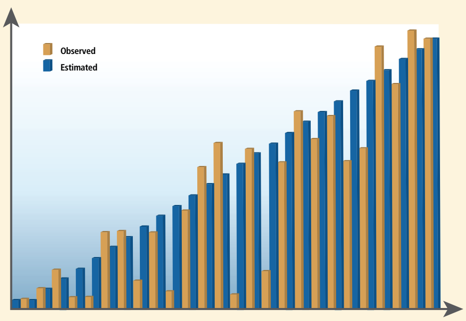
- Include a variable in the model that explains the regional variation. If you see that your model is always overpredicting in the north and underpredicting in the south, for example, add a regional variable set to 1 for northern features and 0 for southern features.
- Use methods that incorporate regional variation into the regression model such as GWR.
- Consult robust regression standard errors and probabilities to determine if variable coefficients are statistically significant. In the ArcGIS Desktop Help Online, see the topic "Interpreting OLS regression results." GWR is still the recommended tool.
- Redefine/reduce the size of the study area so processes within it are all stationary and no longer exhibit regional variation.

## Learning More about Using These Tools

This article provides an introduction to the OLS and GWR tools that were released in ArcGIS Desktop 9.3. ESRI provides many resources for understanding how to intelligently use regression analysis and other spatial statistics tools. A great place to start learning about spatial statistics in general—and these tools specifically—is the ArcGIS Desktop Web help available through the ArcGIS Desktop and Geoprocessing Resource Centers (resources.esri.com) as well as the knowledge bases, communities, and blogs on those sites.

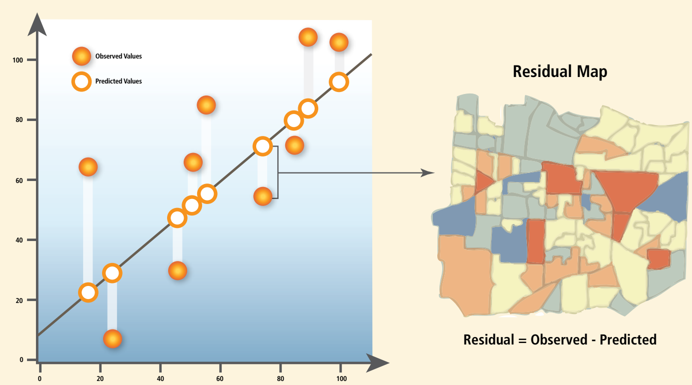
Several training courses offered by ESRI cover spatial statistics. *Understanding Spatial Statistics in ArcGIS 9,* a training seminar, is available at no charge from www.esri.com/training. *Advanced Analysis with ArcGIS,* an instructor-led course, includes an introduction to the Spatial Statistics toolbox, analyzing patterns, and measuring geographic distributions.

A book from ESRI Press, *The ESRI Guide to GIS Analysis,* Volume 2: *Spatial Measurements and Statistics,* by Andy Mitchell explains how these analyses are performed and used effectively.



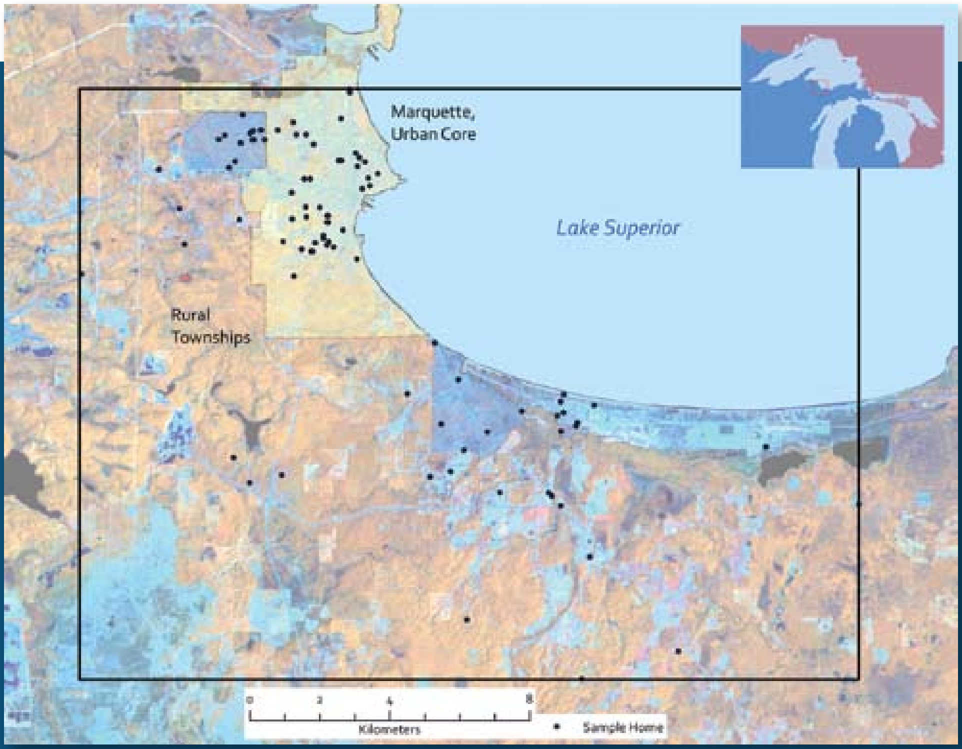

*R-Squared is a measure of model performance, summarizing how well the estimated* y *values match the observed* y *values.*

**Residuals** are the unexplained portion of the dependent variable, represented in the regression equation as the random error term (ε). Known values for the dependent variable are used to build and calibrate the regression model. Using known values for the dependent variable (*y*) and known values for all of the explanatory variables (the *X*s), the regression tool constructs an equation that will predict those known *y* values as well as possible. The predicted values will rarely match the observed values exactly. The differences between the observed *y* values and the predicted *y* values are called the residuals. The magnitude of the residuals from a regression equation is one measure of model fit. Large residuals indicate poor model fit.




*Regression residuals*

Spatial distribution of the houses used to develop the GWR model. The map displays satellite imagery from the Michigan Center for Geographic Data.




# Applying Geographically Weighted Regression to a Real Estate Problem

## An example from Marquette, Michigan

*By Robert Legg and Tia Bowe, Northern Michigan University*

Underpinning geographic thinking is the assumption that spatial phenomena will vary across a landscape. Regression-based models largely ignore this assumption, much to the detriment of spatially varying relationships.

However, ArcGIS 9.3 provides an exciting tool that generates spatially calibrated regression models. Known as Geographically Weighted Regression (GWR), this tool generates a separate regression equation for every feature analyzed in a sample dataset as a means to address spatial variation. (The GWR tool requires an ArcInfo, ArcGIS Spatial Analyst, or ArcGIS Geostatistical Analyst license.)

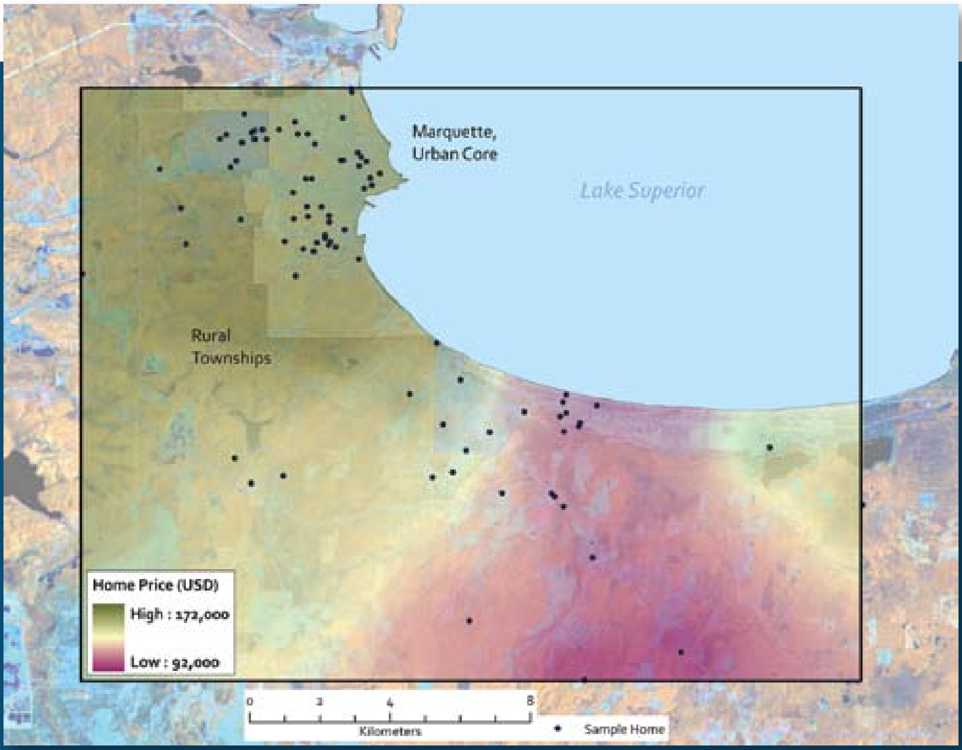
To illustrate these concepts, students in a spatial analysis class at Northern Michigan University (NMU) analyzed the listed sales price for single family houses in Marquette, Michigan, based on location and several other related variables.

Prior to the availability of the GWR tool, linear regression was applied to generate these models. Frequently, students found linear models to be limited because they would often overestimate the asking prices in some neighborhoods while underestimating prices in other neighborhoods. Applying the GWR tool was a way to improve modeling accuracy and ameliorate some of these residual errors.

### Application

To calibrate this study, a sample of 93 homes listed on www.uprealestate.com in March 2008 was used. The coordinates for these houses were recorded in Universal Transverse Mercator (UTM) in North American Datum of 1983 (NAD83) Zone 16N. The listing price parameters included number of bedrooms and bathrooms, house square footage, and lot size. Because the number of bedrooms is closely linked with the square footage of the house, the number of bedrooms was excluded from further analysis. Initial linear regression analysis (entry method) was used for generating a global model predicting the listing price of homes in Marquette, Michigan.

Using the GWR tool *[found in the Modeling Spatial Relationships toolset in the Spatial Statistics tools in ArcToolbox],* a spatially calibrated model was generated using the same dataset. The GWR tool gave separate regression coefficients for each of the 93 houses in the sample. These coefficients were mapped as raster surfaces, and the listing price of a common home (1,500-square-foot floor area with 1.5 bathrooms on a 38,400-square-foot lot) according to spatially varying regression coefficients was generated using the GWR tool in ArcGIS.




*The listing price of a typical house modeled based on spatially varying regression coefficients generated using the GWR tools in ArcGIS.*

## Results

While the linear regression model was found to be significant and had a strong R-squared value of 0.782 ($p = 0.000$), the GWR model improved on these statistics and increased the model's accuracy to an R-squared value of 0.865 ($p = 0.000$). *[R-squared is a measure of goodness of fit. Its value varies from 0.0 to 1.0. Higher values are preferable. See the accompanying article, "Regression Analysis Components—Terms and basic concepts" for more information on these terms.]* In addition, the range in residual value error decreased by $160,000 when using the GWR model instead of the linear model.

The coefficient surfaces generated using the GWR tool were also helpful for identifying the spatial patterns apparent in the study area. For example, the lot value coefficients indicate that as lots are located nearer the urban core and farther from the rural townships, lot square footage price increases. In contrast, coefficients suggest that the larger the house, the less it contributes to the listing price (again, as properties are located nearer the urban core and farther from the rural townships).

This pattern may be indicative of the age of houses in rural areas. Sprawling rural subdivisions tend to have newer houses than neighborhoods in the urban core, yet land values are lower. These newer houses command a higher listing price per square foot according to the data analyzed. This pattern may also indicate a response to differences in millage rates between the townships and urban core. *[Millage is the tax rate on property expressed in mills per dollar of value of the property.]* Taxation rates in the urban core are typically twice as high as rates in rural townships in the state of Michigan (according to the Michigan Department of the Treasury in 2008). Higher millage rates may discourage the construction of newer developments in the urban core.

In conclusion, the user-friendly GWR tool offers a sophisticated basis to quantify and dissect spatial patterns across a study area. Application of GWR offers a noticeable improvement over linear regression and helps to promote spatial thinking in students enrolled in courses at NMU.

For more information, contact Robert Legg in the Department of Geography at Northern Michigan University (rlegg@nmu.edu).

## About the Authors

Robert Legg (rlegg@nmu.edu) is an assistant professor at Northern Michigan University. He specializes in spatial data modeling, remote sensing, and cartography. Legg received his master's degree in remote sensing from the University of Aberdeen, Scotland and doctorate in geography from Trinity College in Dublin, Ireland.

Tia Bowe (tbowe@nmu.edu) is a professional cartographer majoring in GIS at Northern Michigan University. Currently, she holds an associate's degree in geographic information systems from Hocking College in Nelsonville, Ohio.

## Bibliography

Fotheringham, A. Stewart, Chris Brunsdon, and Martin Charlton. *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships,* Wiley. Chichester, United Kingdom, 2002.

Michigan Center for Geographic Data. Spatial data retrieved March 2008.

Michigan Department of the Treasury, https://treassecure.state.mi.us/, (data collected October 2008).

Mitchell, Andrew. *The ESRI Guide to GIS Analysis,* Volume 2: *Spatial Measurements and Statistics,* ESRI Press. Redlands, California, 2008.

Rogerson, Peter A. *Statistical Methods for Geographers: A Student's Guide,* SAGE Publications. Los Angeles, California, 2006.

# Get a New Strategy

## Five easy ways to streamline geospatial metadata production

*By Jessica L. Zichichi and Caroline S. Roberts, Innovate!, Inc.*

Is **metadata** something that your organization can just **never** seem to get to?

Is developing **metadata** for your resources **difficult** and time consuming?

Do you think **metadata** compliancy is just **too complicated**?

If so, you may want to rethink your metadata development strategy. Simply making a few changes in your metadata production process will not only reduce the time it takes to develop metadata but will also greatly improve the quality of your records. Use the five steps provided below and you will be creating high-quality, compliant metadata before you can say, "Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata!"

This tutorial provides some basic recommendations for improving metadata production. It assumes the reader knows how to use ArcGIS ArcCatalog and has some familiarity with geospatial data and metadata topics in general. Although there are currently two standards available for documenting geospatial metadata in the United States—the Federal Geographic Data Committee's (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) and the North American Profile (NAP) of ISO 19115/19139—this tutorial focuses on implementing the FGDC CSDGM. Although focused specifically on the implementation of the FGDC CSDGM standard, the principles and techniques described are applicable to those implementing the NAP of ISO 19115/19139.

### Step One

#### Create a Metadata Implementation for Your Organization

Developing a metadata implementation is an important but often overlooked step in metadata development. In fact, many people are not familiar with the concept of developing a metadata implementation. A metadata implementation defines how to interpret a metadata standard for a particular group or organization. Because many metadata standards are large and often include a number of free-text fields, it can be useful to review the standard with your organization's objectives in mind and develop an organizational implementation specifying requirements that fit your needs. This will help standardize the way your group produces metadata.

Your organization may develop metadata for a number of interrelated reasons that can include providing a record of processing, serving as a legal document, or enabling resource sharing. The nature of your metadata needs will determine how your implementation is structured.

- If your concerns include FGDC minimum compliancy, you will need to include FGDC CSDGM sections one and seven (required for minimum compliancy).
- If data quality and processing steps are important, section two should be included.
- If your data includes attributes, then section five will be required.
- If you distribute your resources, you will want to review section six.

It can be useful to consider each section when creating your implementation, prioritizing those sections that are most critical to your needs.

Depending on the size of your organization and the number of metadata creators, the steps needed for developing an implementation may vary. For large organizations, it may be instructive to form a workgroup to review your chosen standard, define language for important fields, and identify the fields that you will require. Once these issues have been decided, you can develop a template (described in the fifth step in this article) along with descriptive documentation for your metadata developers. An example implementation developed by the United States Environmental Protection Agency (EPA) for geospatial metadata (called the EPA Geospatial Metadata Technical Specification Version 1.0) is available at EPA's Web site (www.epa.gov/geospatial/policies.html).

Taking the time to develop an implementation as a first step in improving metadata production will greatly assist in making subsequent metadata development easier. You will improve consistency across your organization while saving time and ensuring that your records include the information you want. For additional background on metadata topics, visit the Innovate metadata training Web site. The training modules provided at this Web site can help familiarize you with the basics of the FGDC CSDGM, the NAP of ISO 19115/19139 standard, metadata catalogs, and contributing information to Geospatial One-Stop.

### Step Two

#### Choose an Appropriate Metadata Editing Tool

Developing metadata can be especially challenging if you are not using the right tools to help streamline and automate the process. Making the right choice in editing tools will increase your productivity considerably. Some considerations for choosing a tool may include software availability (freeware, licensed, or purchased product), the editing environment (Web based or desktop), flexibility, ease of use, access to help, and support for full FGDC and/or ISO standards. In some cases, your organization may choose a combination of available

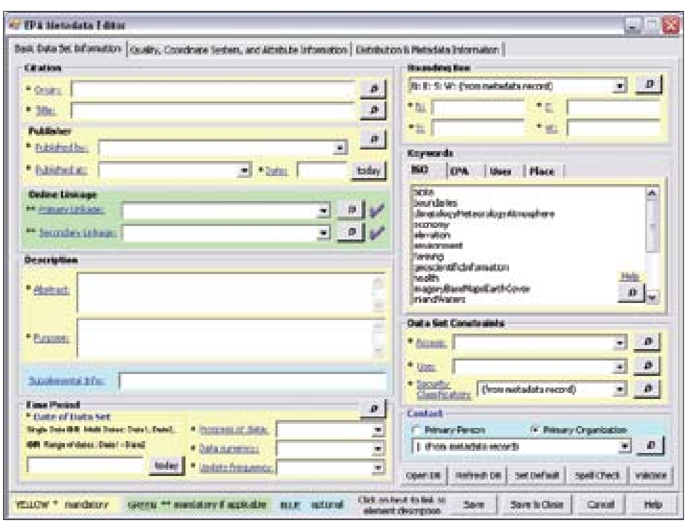
Make a few simple changes in metadata production and greatly improve the quality of your records.

tools to meet your needs. It is important to evaluate your needs against the features that particular tools offer when making a decision.

If you would like more information about tools or considerations for choosing one, a number of resources are available. The FGDC Web site includes information on metadata tools and choosing the appropriate tools for your needs. This information covers tools for both FGDC CSDGM and ISO 19115/19139 editing.

In addition, the Innovate metadata training Web site provides information about popular tools and considerations for using them. A metadata tools comparison spreadsheet (located with the sample data) is available with Microsoft PowerPoint training modules that contain information about considerations for choosing tools (introductory slides, module 3).

One popular choice is the EPA Metadata Editor (EME) version 3.0. EME is a freely available ArcCatalog extension that provides a number of key features including clearly identifiable requirements, buttons that autopopulate a record with your default information, use of a configurable Microsoft Access database to allow you to specify defaults, and an integrated help system. To access the EME and related resources (e.g., training videos, frequently asked questions, or source code) go to the EME Web site.



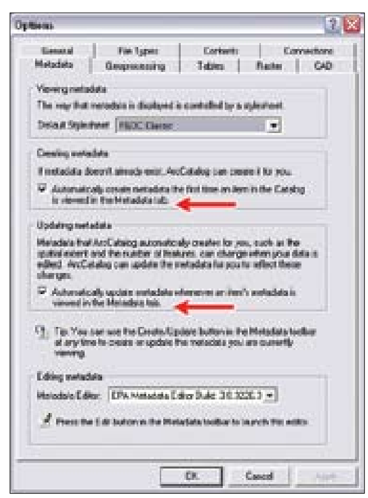
*The EPA Metadata Editor (EME) interface*

## Step Three
### Configure Your Metadata Synchronizers

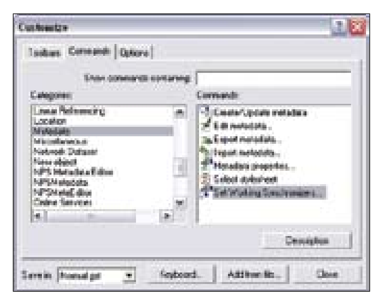
Many people who create metadata are not aware of metadata synchronizers. In fact, many metadata developers are using synchronizers without knowing it. This is because synchronization is an automated process in ArcCatalog that is enabled by default during installation. Synchronization is the process of inserting information about your dataset into your metadata, which may include attribute information, spatial extent, coordinate system information, or other details. Enabling synchronization causes ArcCatalog to insert these details into your metadata whenever you click on a dataset in ArcCatalog. This is beneficial because it automates the process of documenting these details and helps ensure metadata integrity.

However, the process may have some unintended side effects such as inserting information you do not want in your records, simultaneously inserting both FGDC and ISO elements, or inserting noncompliant information. To control this, you should configure your synchronizers.

ArcCatalog allows you to enable and disable your synchronizers and select which synchronizers to use. Turning synchronization on or off is performed within the Metadata tab of the ArcCatalog settings interface by choosing Tools > Options and selecting the Metadata tab. In this interface, you can enable or disable the synchronization process and select which synchronizers to use by adding the Set Working Synchronizers button to an ArcCatalog toolbar. This button allows you to select which default synchronizer to use (FGDC, ISO, or Geography Network). The drawback to this approach is that it results in an all-or-nothing approach. Synchronization is either entirely enabled or entirely disabled. Some users may want additional flexibility.



*Turning synchronizers on or off in ArcCatalog*



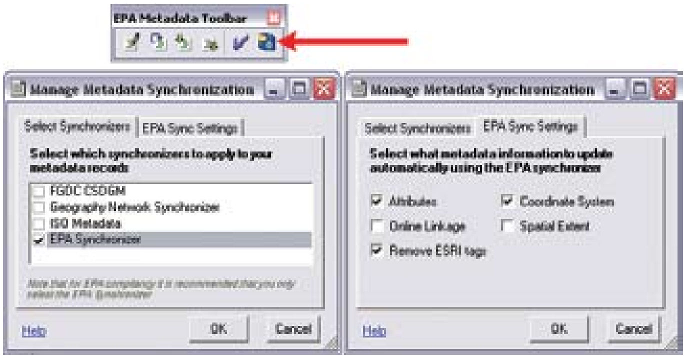
*Set working synchronizers in ArcCatalog*

An alternative to the all-or-nothing approach just described is to use the EPA Synchronizer that comes with EME version 3.0. The EPA Synchronizer allows you to specify which elements to synchronize with the dataset. That way, your organization can choose which elements to update as part of the synchronization process. You can also specify which synchronizers to use within the EPA Synchronizer interface. Access the EPA Synchronizer from a button on the EME toolbar. For more information, visit the EPA EME Web site and access the EPA Synchronizer training video in module 2. For additional, more general information about how synchronizers work, visit the Innovate metadata training Web site and access the introductory training modules (module 2).

*Continued on page 48*

# Get a New Strategy

*Continued from page 47*



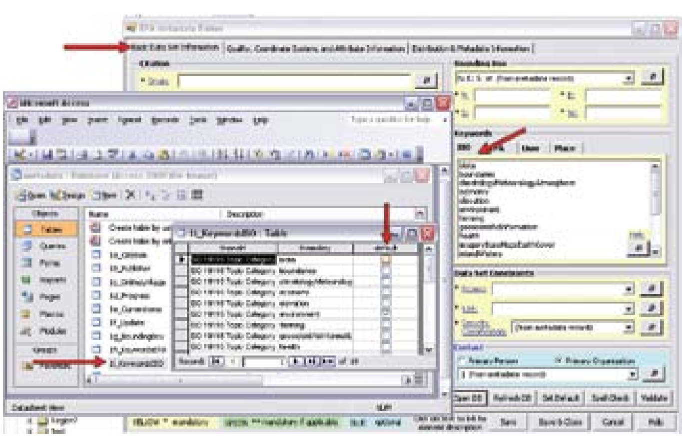

*Using the EPA Synchronizer*

## Step Four

### Customize and Share Your EME Database

One of the biggest benefits of EME is the ability to customize it by changing information in the EME database. EME utilizes a simple Microsoft Access database to populate the drop-down lists and defaults within the user interface (UI). You can modify the contents of the database to reflect your defaults using Microsoft Access, then use that information in the EME UI.

To do this, click the Open DB button in the EME UI. When the database opens, you will see a list of tables that are available for editing. The table names reflect their location within the EME UI. For example, table 1b_Publisher contains information found on tab 1 of the EME UI. Similarly, table 2a_Completeness contains information found on tab 2 of the EME UI. This design simulates the flow of elements as shown in the EME UI so that it is easy for users to identify which tables they would like to edit. You can add information to your table of choice to suit your metadata needs. To make your information the default within EME, select the check box for your entry in the default column within the table. If you select a new default for your information, make sure to deselect the currently existing default.



*The EME database structure*

The EME database is located in the EME installation directory. By default, it's called metadata.mdb and is installed in C:\Program Files\Innovate! Inc\EPA Metadata Editor. However, you can change the location of the EME database and specify that EME point to this new location. This can allow your organization to share the EME database across multiple parties. To change the location of the EME database, access the "Setting up the EME Database" section of the EME help file.

## Step Five

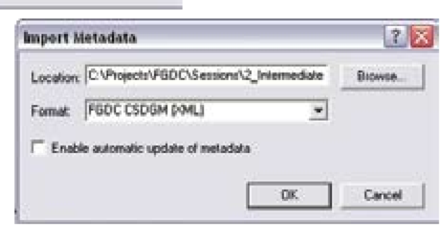
### Create Metadata Templates

Once you have a standard approach for developing metadata, you may want to consider creating metadata templates. Using templates can provide even greater consistency and automation within your metadata creation practices. As the name implies, metadata templates are used as a basis for developing metadata by providing default information. You can create a template by starting from scratch or by using a pre-existing metadata record. If you already have a record that contains information that your organization can reuse, export it to XML format (FGDC CSDGM specifically) and save the file on your machine. Then you can import that file and use it as a basis for other resources. Be careful when importing metadata templates, as they overwrite all pre-existing metadata. More information on creating templates is available in the introductory section of module 3 at the Innovate metadata training Web site.

Depending on the nature of your data, it may be useful to create a series of templates organized around different topics. For example, you may consider creating templates that reflect the different types of geospatial assets used by your organization (e.g., downloadable data, live data and maps, or applications), or it may make more sense to create a series of templates that reflect the types of data maintained by your organization.

While going through all the steps listed in this article is recommended for improving metadata creation, it can be beneficial to start by incorporating just one or a combination of these suggestions. Whatever your needs, taking a little time to initiate some better metadata practices will be well worth your investment and will increase the value of your resources in the long run.


*Exporting a metadata record*




*Importing a metadata record*

***For more information, see* Creating and Maintaining Metadata Using ArcGIS Desktop*, a Web course, and* Metadata: Tips and Tricks*, a free Web training seminar. Both are available at www.esri.com/training.***

| Site | URL | Resources available |
|---|---|---|
| EPA Metadata Editor (EME) Version 3.0 | www.epa.gov/geospatial/eme.html | Freely available ArcCatalog metadata extension |
| Federal Geographic Data Committee | www.fgdc.gov/metadata/geospatial-metadata-tools | Information on metadata tools and choosing the appropriate tools for both FGDC CSDGM and ISO 19115/19139 editing |
| Innovate!, Inc. | innovateteam.com/projects/epa-and-partners-geospatial-metadata-training/ | Training modules on metadata topics and the basics of the FGDC CSDGM, the NAP of ISO 19115/19139 standard, metadata catalogs, and contributing information to Geospatial One-Stop |
| U.S. Environmental Protection Agency | www.epa.gov/geospatial/policies.html | EPA Geospatial Metadata Technical Specification Version 1.0 |

*Resources*

For more information, contact

Jessica Zichichi
Innovate!, Inc.
Charleston, South Carolina
Tel.: 843-277-0799
E-mail: jzichichi@innovateteam.com

**About the Authors**

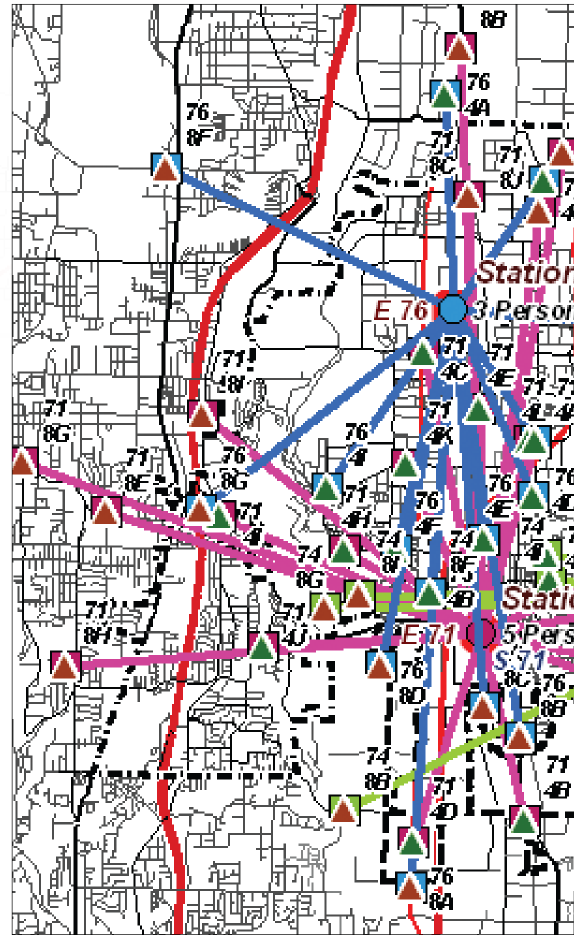
Jessica L. Zichichi is the vice president of the geospatial solutions team at Innovate!, Inc. She has been working in the field of GIS for more than 10 years and holds a master's degree in computer science and bachelor's degrees in geography and environmental studies. Her recent GIS efforts include enterprise geospatial solutions, geospatial metadata implementation and training, and geospatial policy and planning. She is registered as an FGDC-certified metadata trainer and has recently finished leading a free, comprehensive metadata training program through an FGDC-sponsored Cooperative Agreements Program grant.

Caroline S. Roberts, GISP, has been working in the field of GIS for more than 10 years. She holds a master's degree in marine science and bachelor's degree in natural resources. Her current projects include utilizing GIS for marine environmental remediation activities, aeronautical surface mapping for obstruction analysis, and geospatial metadata training. Roberts has recently finished leading a free, comprehensive metadata training program through an FGDC-sponsored Cooperative Agreements Program grant.

# Convincing the Chief

## Proving that time-based networks really work

*By Mike Price, Entrada/San Juan, Inc.*




Many recent *ArcUser* articles have shown how to design, build, and run time- and distance-based travel networks for emergency response modeling. These model posted or customized speeds, global turn rules, and slope corrections. Previous articles assumed that the modeling parameters and analytical findings were correct.

This tutorial uses data from Fire District (FD) 37 in South King County, Washington, and re-creates two analyses that were recently performed by agency staff to validate the district's time-based network travel model. The ArcGIS Network Analyst extension's OD (Origin-Destination) Cost Matrix will be used to test and validate actual timed trial runs for several stations.

Previous tutorials that appeared in the July–September 2007, October–December 2007, and Summer 2008 issues of *ArcUser* can be used to review the ArcGIS Network Analyst modeling method and the concepts of distribution and concentration. These articles provide more information on how emergency responders use time as a response measure.

### Getting Started

To begin the exercise, visit the *ArcUser Online* Web site at www.esri.com/arcuser and download the sample dataset for this tutorial. This is the fourth in a series using Fire District 37 data, so the parent folder is named FD37_4.

1. Unzip the archived sample dataset at or near the root directory of a local drive. The archive creates a folder called FD37_4.
2. Open ArcCatalog and explore the data in FD37_4. Notice that there are three subfolders named DBFFiles, SHPFiles, and Utility. All exercise data is registered in Washington State Plane NAD83 North Zone U.S. Feet (WASP83NF).
3. Inside SHPFiles, notice the WASP83NF folder. This shapefile subfolder contains several shapefiles and layer files that will be used in this exercise.
4. Inspect the DBFFiles folder and see that Time_Runs_1 contains run data for four FD 37 fire stations, recorded at four- and eight-minute travel points.
5. Open RunSummary1.xls and see that it contains one worksheet, Statistical Summaries, that is ready to tabulate statistics for the four- and eight-minute runs for each station.
6. Leave ArcCatalog open.

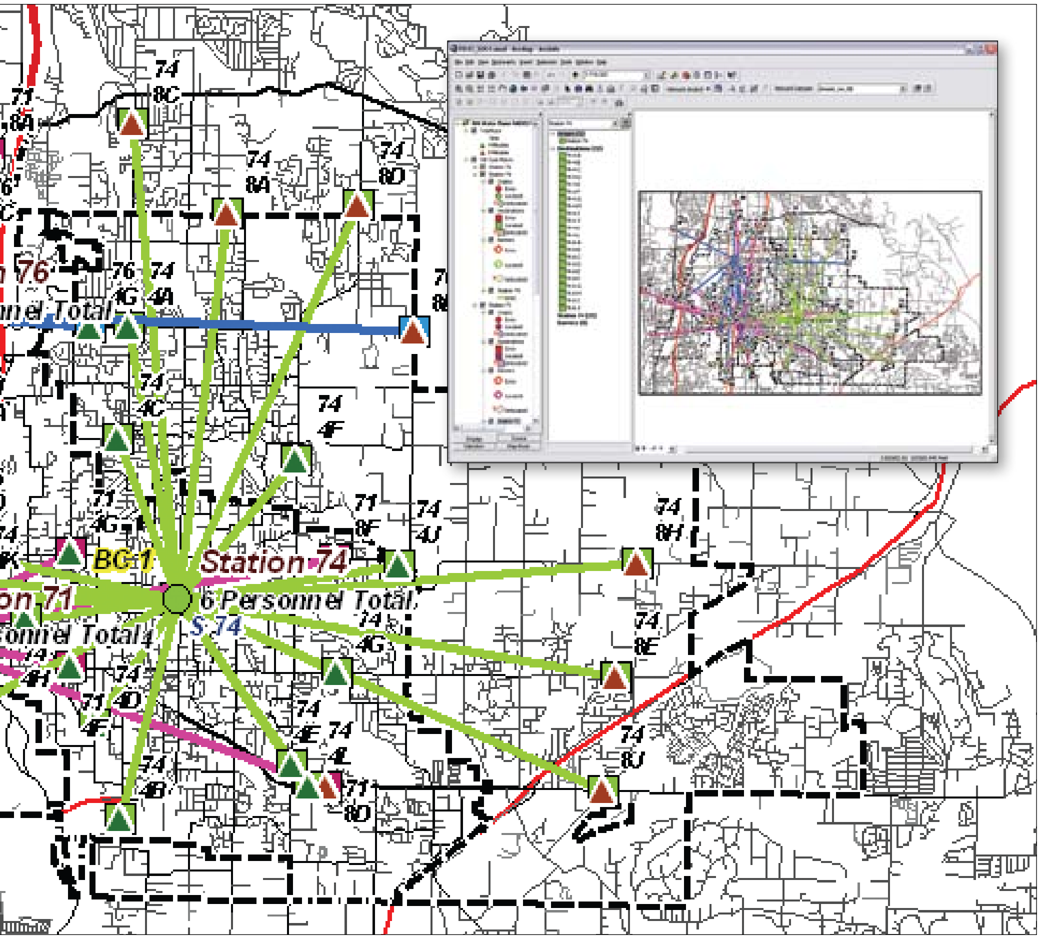
To gather data for this project, station duty crews at each station were instructed to drive 10 different routes from their station to locations on the street network. They drove the routes at speeds at or near accepted response speeds, in light to moderate daytime traffic, and in good weather. The apparatus officer noted the exact location of the four-minute and eight-minute time point on each route. These time points were then mapped and are available for this exercise as a dBASE table including WASP83NF coordinates.

### Building a Network Dataset with Network Analyst 9.3

In ArcCatalog, verify that the Network Analyst extension is available and active.

1. Navigate to FD37_4/SHPFiles/WASP83NF and locate streets_nw.shp. Preview the attribute table for this layer. Notice that it contains network-ready data including fields for a time cost in minutes, length in miles, and one-way flags. These fields will be used to build a network dataset.
2. In the Catalog tree, right-click streets_nw.shp and select New Network Dataset. Accept the default name and click Next.
3. Inspect Connectivity and accept End Point as the only connector; click Next. The streets use geometry rather than elevation to define crossing relationships, so do not modify connectivity.
4. Click Next and accept Global Turns; click Next again.
5. In the network attributes window, click the Add button to add an attribute. In the new Add New Attribute dialog box, type Length_Mi for Attribute, choose Cost for Usage Type, choose Miles for Units, and leave Data Type as Double. Notice that Minutes and Oneway are both default parameters because the primary test will be fastest travel time, not the shortest distance.
6. Highlight Minutes and click the Evaluators button. In the Evaluators dialog box, select the Default Values tab. For the Turn element, click on the word Constant to see four options. These options now include a new one in ArcGIS 9.3 called Global Turn Delay. Select this option and press F12.
7. A new Global Turn Delay Evaluator appears. Notice that this evaluator supplies defaults but allows modification of the intersection approach angles and the delay times. Also notice, that feature classes can be used to create complex relationships between different street classes.
8. Save the map document.

The streets in this sample dataset are rather simple and will only require the use of one Local class. The Seconds field in this dialog box accepts values for delays for straight travel (with and without crossing roads), right and left turns, and U-turns. After tuning the streets in the sample dataset, it was determined that the delays shown in Table 1 work best throughout the district.




**What You Will Need**

- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- Microsoft Excel
- ArcGIS Network Analyst extension
- Sample dataset from *ArcUser Online*

*This exercise models data from Fire District 37 in South King County, Washington, and re-creates two analyses to validate the district's time-based network travel model using the ArcGIS Network Analyst extension's Cost OD (Origin-Destination) Matrix.*

| Direction | Description | Sec |
|---|---|---|
| Straight | From Local to Local Road across No Roads | 0 |
| Straight | From Local to Local Road across Local Road | 1 |
| Reverse | From Local to Local Road | 30 |
| Right Turn | From Local to Local Road | 2 |
| Left Turn | From Local to Local Road | 4 |

*Table 1: Delay values*

To add these values to this project, type the values for these delay values into the Seconds field, or load a prebuilt XML time set from the \Utility folder created by the sample dataset archive. To load the XML file, click the Load From File button on the dialog box, navigate to \Utility, and select GlobalTurns_00_01_02_04.xml. The optimal values will post automatically.

Turn window width can be changed interactively. After using the mouse to resize portions of the colorful azimuth graphic, reset or retype Width values (in degrees) to restore the defaults or reload the XML file. Click OK to close the Global Turn Delay Evaluator, click OK to accept the updated Evaluators, and click Next. Accept Driving Direction defaults and click Next again.

A summary of the network dataset parameters that have been set appears in a scrolling window. Select and copy this text into a WordPad file. Name the file with the creation or last modification date and save the text file in the \SHPFiles\WASP83NF folder. Inspect this file carefully and observe the new global turn rules.

Click Finish, then Yes to build the new network dataset. Once this is completed, close ArcCatalog and open ArcMap.

## Loading and Mapping Network Streets and Time Runs

In ArcMap, open the FD37_SOC4 ArcMap document file located in the FD37_4 root folder. Inspect this map document. The data is very similar to data used in previous District 37 tutorials. However, in this case, only three stations appear. These stations were selected to show variety within the district. The project opens in Layout View and shows location, apparatus, and staffing for Stations 71, 74, and 76. The Time Runs layer, at the top of the TOC, does not have a valid data connection. At the end of this next process, that problem will be fixed.

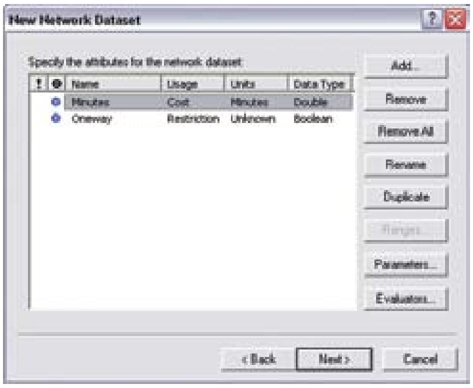
Station 71 is an engine/squad station with five on-duty personnel. It is located just south of the Kent downtown area. Station 74 includes a ladder, a squad, and a battalion chief (six personnel), located on high ground in eastern Kent. It is situated on an arterial street and much of the surrounding land use is residential. Station 76 is a three-firefighter engine station located in the northern Warehouse district.

1. Before adding data to the project, confirm that the Network Analyst extension is available and its toolbar is visible.
2. Open an empty Network Analyst Window. Click the Add Data button on the Standard toolbar and navigate to \SHPFiles\WASP83NF.
3. Load the network dataset streets_nw_ND. When prompted, do not load other participating feature classes.
4. In the TOC, drag streets_nw_ND below the Network Streets and turn it off.
5. Navigate to the \DBFFiles folder and load Trial_Runs_1.dbf.

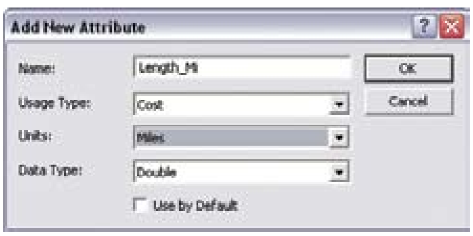
*Continued on page 52*

# Convincing the Chief

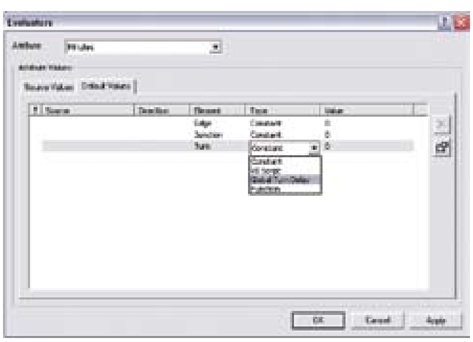
*Continued from page 51*



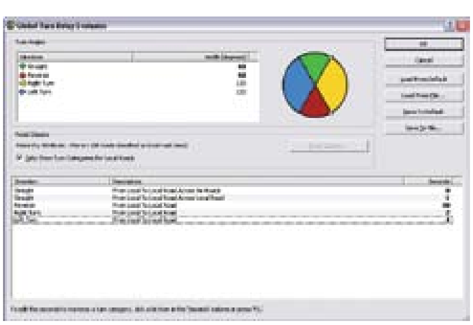

*In ArcCatalog, create a new network dataset.*




*Create a new attribute, Length_Mi, for this network dataset with Cost as the Usage Type and Miles as the Units.*




*Set the default values for the Minutes evaluator and use the new Global Turn Delay for the type of turn.*




*Set the Seconds delays field values in the Global Turn Delay evaluator as shown here and listed in Table 1.*

6. Open the table for this file and locate the East and North fields. Using these and applying the correct Washington State Plane coordinates, the data can be registered.
7. In the TOC, right-click Trial_Runs_1.dbf and choose Display XY Data. Set the X Field to East and the Y Field to North. Click Edit.
8. In the Spatial Reference Properties dialog box, click Select and specify NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet from the choices under Projected as the coordinate system. Click OK and OK to exit both dialog boxes.
9. After Trial_Runs__1Events loads, right-click on it and choose Data > Export Data. Apply the data frame's coordinate system, name it Trial_Runs_1.shp, and store the file in \SHPFiles\WASP83NF. Do not add the shapefile to the data frame.
10. Next, double-click on Time Runs, the layer that has a broken data connection, and set Trail_Runs_1.shp as its data source. Remove Trial_Runs__1Events.
11. Make the Trial Runs layer visible and inspect its points. Each point is labeled to show the station, time interval, and run code. Switch from Layout View to Data View.
12. Save the project.

## Building and Solving an OD Cost Matrix for Station 71

The next task will be building three origin-destination matrices—one for each station and its time run data. There are many ways to build and analyze this run data, but creating a separate matrix for each station will allow quick viewing of statistical data for each time subset. There are more sophisticated ways to model and present this data, but this exercise uses a simplified approach. After creating the matrix for Station 71, the process will be repeated for Stations 74 and 76.

1. Be sure that the Network Analyst toolbar and window are available. Click on the Network Analyst drop-down in the toolbar window and choose New OD Cost Matrix.
2. In the TOC, right-click on OD Cost Matrix (just created) and select Properties. In the General tab, rename the layer Station 71. Click the Accumulation tab and check the Length_Mi and Minutes boxes. In the Analysis Settings tab, verify that Impedance is set to Minutes.
3. Open attribute tables for Time Runs and Selected Fire Stations layers. In the Selected Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.
4. In the Network Analyst window, right-click on Origins and select Load Locations. In the Load Locations dialog box, set Sort Field to INDEX. For the Name Property, click on Field and choose LABEL. Under Location Position, choose Use geometry and specify 500 and Feet for the search tolerance. Click OK. Verify that the single Station 71 record in Selected Fire Stations is selected.
5. Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL. Be sure that the correct (i.e., selected) 22 records load. If non-Station 71 records load, delete them and reload the correct ones. (Note: Do not delete records when modeling Concentration because the tabular join to INDEX, necessary for this operation, will fail.)
6. Create new OD Matrices for Stations 74 and 76 using this procedure. Be sure to select and load the correct origin and destination records. Rename each OD matrix and group all matrices in one group layer named OD Cost Matrix Group.
7. Save the project.


*Create an events layer from Time_Runs_1.dbf and export the georeferenced data to a shapefile.*

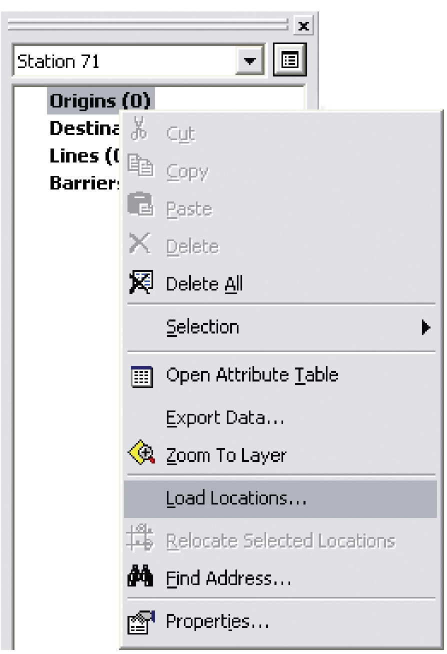
## Solving and Analyzing OD Cost Matrix Results

The three matrices are now ready to solve.

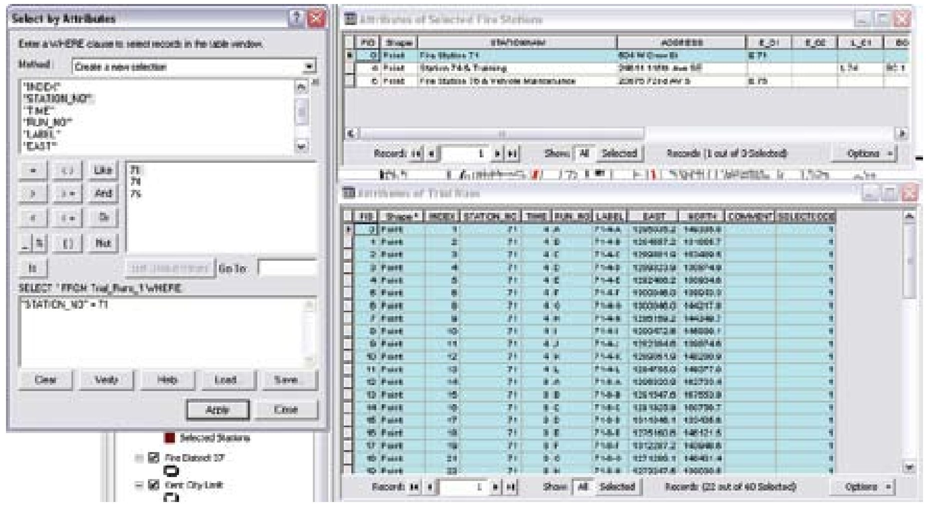
1. In the OD Matrix group, right-click on the matrix for Station 71 and select Solve. Under Destinations, Lines will be populated.
2. Right-click on Lines, choose Properties, and use the General tab to rename it Station 71. Using Properties, also change the line width to a three-point width and apply bright distinct colors.
3. Repeat this process for the Station 74 and 76 matrices.
4. Save the map document again.

This exercise builds two-node vector lines that show the connection between a fire station and its trial run points. Network Analyst actually posts the shortest travel time and route distance in the Lines table. Although the route is represented by a straight line, it actually follows the fastest network.

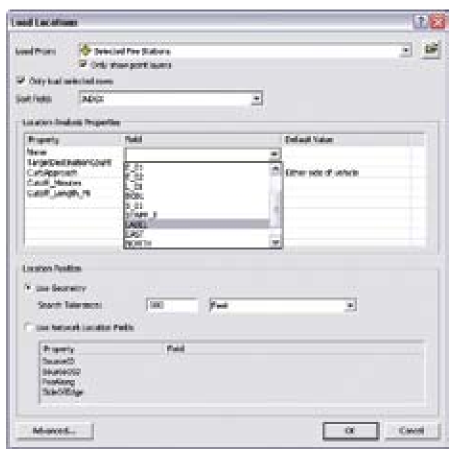
1. Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables. Select the four-minute records for each station by querying out records with Total_Minutes less than 5.0.
2. To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total_Minutes field and choose Statistics.



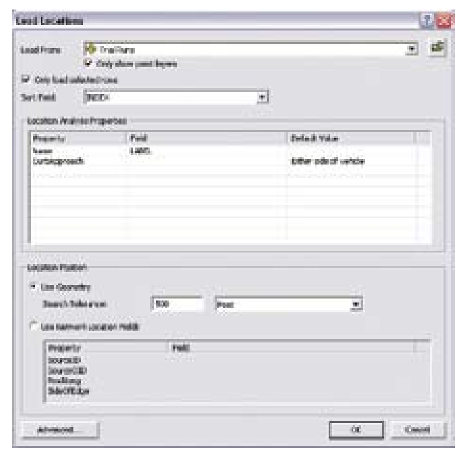

*In the Network Analyst window, load the locations in the OD Cost Matrix for Station 71 by right-clicking on Origins and choosing Load Locations.*



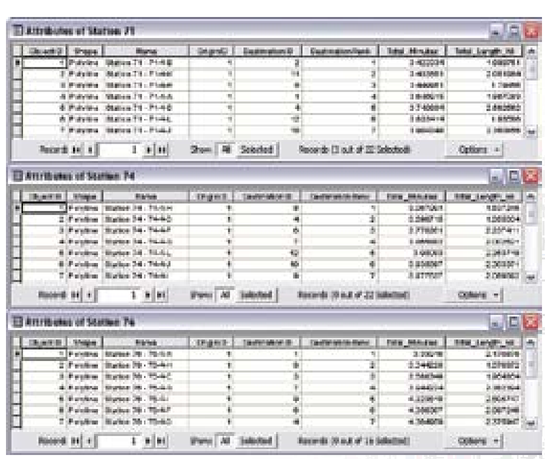
*In the Selected Fire Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.*



*In the Load Locations dialog box for Selected Fire Stations, set Sort Field to INDEX, set the field for Name property as LABEL, and under Location Position, choose Use Geometry and specify 500 and Feet for the search tolerance.*



*Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL.*



*Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables.*

Continued on page 54

# Convincing the Chief

*Continued from page 53*

3. Inspect the statistics for the sub-four-minute runs for each table, particularly the Mean and Standard Deviation values.

It certainly would be nice to place this data in a table so it could be studied. To quickly post this summary data, open the Excel spreadsheet template, RunSummary1.xls, provided in the sample dataset, and copy values from the four-minute statistics generated for each station to the appropriate cells in the spreadsheet.

In ArcMap, under the four-minute statistics for Station 71, copy and paste the Mean value from the summary spreadsheet to the Mean, Minutes field in the attribute table for Station 71 in ArcMap. Repeat for the Run Count; Maximum, Minutes; Minimum, Minutes; and Standard Deviation fields. Gather the same statistical data for Stations 74 and 76.

To generate statistics the eight-minute run data for each station, simply click the Options tab on the table for each station and chose Switch Selection. Copy and paste the eight-minute run statistics into the spreadsheet.

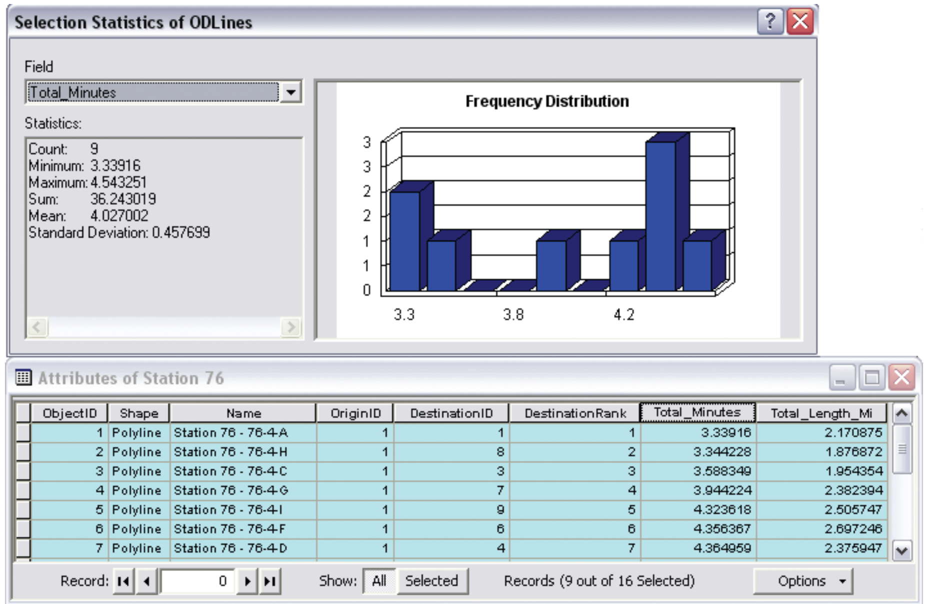
Now that the time Runs for three District 37 fire stations have been summarized, inspect RunSummary1.xls. Notice that the mean values for all four- and eight-minute runs are very close to the target times. In each station's travel area, the average actual time is very close to the targets. Each station's dataset includes records that represent times greater than and less than the targets. Smaller standard deviation values suggest tighter clustering around the mean. In general, District 37 managers are very satisfied with the performance of this travel network. These trial runs have shown that slightly liberal turn rules and posted speed are valid measures of emergency response capability.

## Summary

This exercise used the Network Analyst OD Cost Matrix to compare actual measured travel times to modeled values. Overall, this analysis demonstrated a very good correlation between modeled and actual times. District 37 personnel continue assessing travel times and testing additional details that might improve the response model. As a corollary to this exercise, District 37 has also recognized the potential to use an OD cost matrix to test and validate actual travel times to specific incidents.

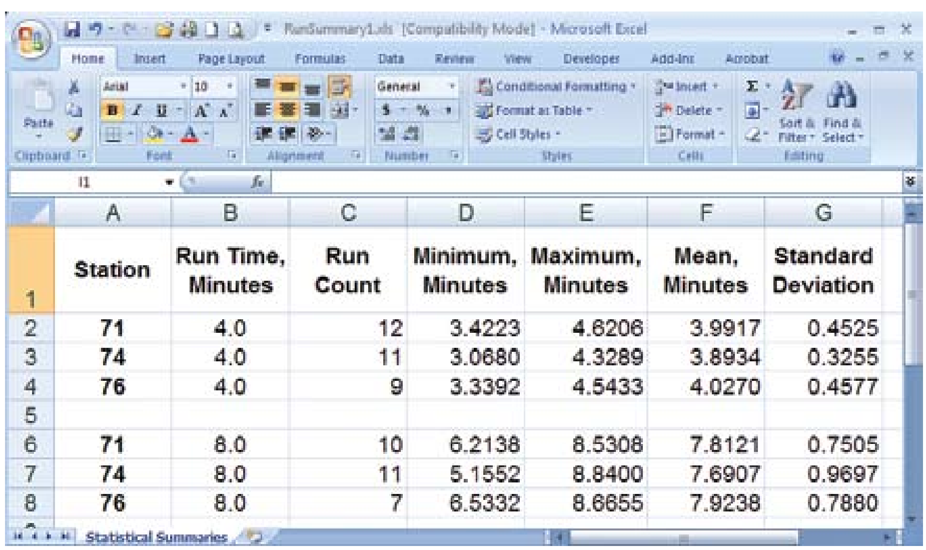

## Acknowledgments

Special thanks go to the administration and staff of Fire District 37, South King County, Washington, and the many FD 37 and Kent City staff who provided data for this exercise. This allowed the mapping and evaluation of actual run time data captured by district firefighters and modeled real travel time data on city streets.


| ObjectID | Shape | Name | OriginID | DestinationID | DestinationRank | Total_Minutes | Total_Length_Mi |
|---|---|---|---|---|---|---|---|
| 1 | Polyline | Station 76 - 76-4-A | 1 | 1 | 1 | 3.33916 | 2.170875 |
| 2 | Polyline | Station 76 - 76-4-H | 1 | 8 | 2 | 3.344228 | 1.876872 |
| 3 | Polyline | Station 76 - 76-4-C | 1 | 3 | 3 | 3.588349 | 1.954354 |
| 4 | Polyline | Station 76 - 76-4-G | 1 | 7 | 4 | 3.944224 | 2.382394 |
| 5 | Polyline | Station 76 - 76-4-I | 1 | 9 | 5 | 4.323618 | 2.505747 |
| 6 | Polyline | Station 76 - 76-4-F | 1 | 6 | 6 | 4.356367 | 2.697246 |
| 7 | Polyline | Station 76 - 76-4-D | 1 | 4 | 7 | 4.364959 | 2.376947 |

*To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total_Minutes field and choose Statistics.*



| Station | Run Time, Minutes | Run Count | Minimum, Minutes | Maximum, Minutes | Mean, Minutes | Standard Deviation |
|---|---|---|---|---|---|---|
| 71 | 4.0 | 12 | 3.4223 | 4.6206 | 3.9917 | 0.4525 |
| 74 | 4.0 | 11 | 3.0680 | 4.3289 | 3.8934 | 0.3255 |
| 76 | 4.0 | 9 | 3.3392 | 4.5433 | 4.0270 | 0.4577 |
| | | | | | | |
| 71 | 8.0 | 10 | 6.2138 | 8.5308 | 7.8121 | 0.7505 |
| 74 | 8.0 | 11 | 5.1552 | 8.8400 | 7.6907 | 0.9697 |
| 76 | 8.0 | 7 | 6.5332 | 8.6655 | 7.9238 | 0.7880 |

*To quickly post this summary data, open the Excel spreadsheet template, RunSummary1.xls, provided in the sample dataset and copy values from the four-minute and eight-minute statistics generated for each station to the appropriate cells in the spreadsheet.*

# Asking the Right Questions

## *Getting started using queries*

*By Monica Pratt,* ArcUser *Editor*

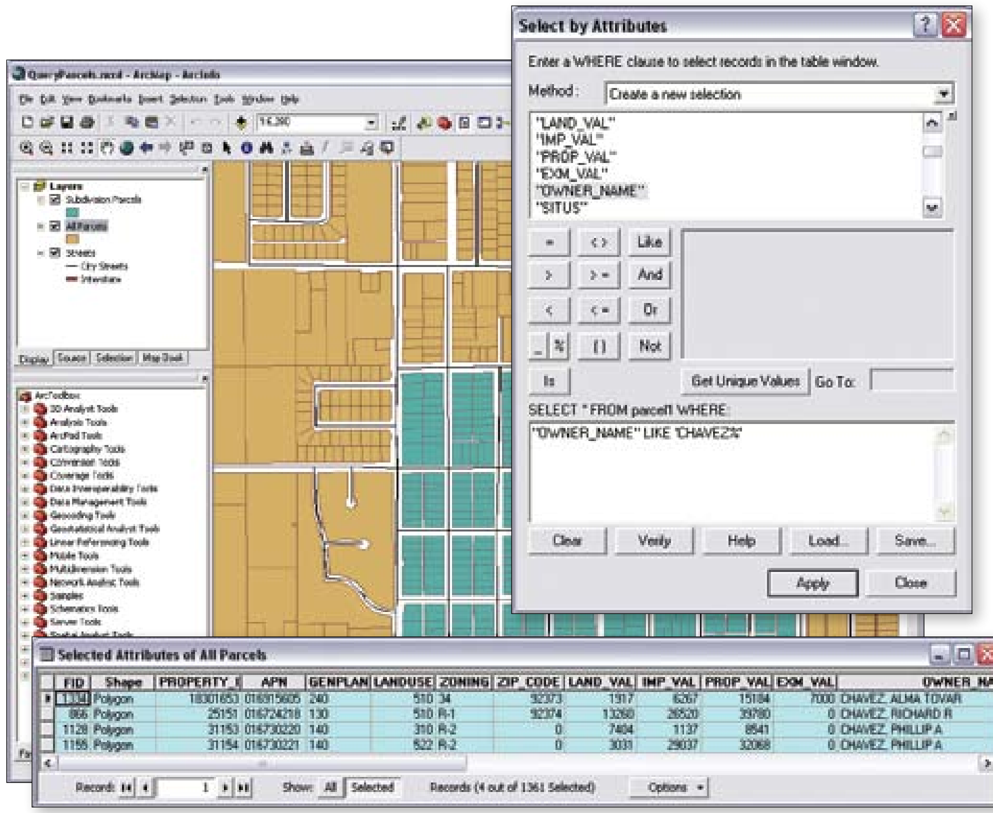
One of the defining characteristics of GIS is the ability to ask questions (and get answers) in a spatial context. These questions or queries are requests for information that are posed in a specific fashion.

Queries are expressed in a formal way using Structured Query Language (SQL). This language is composed of a set of commands and rules that are used to ask questions of a database. SQL, which has been implemented for nearly every DBMS, comes in many subtly different "flavors" depending on the database being queried. However, the details of these differences are not a concern when using the ArcMap application in ArcGIS Desktop. The software detects the characteristics of the underlying database being queried and modifies the interface so SQL statements will be created using the appropriate search terms and information. The user is not required to understand the SQL format for the specific database being queried.

There are two types of queries: attribute and location. Attribute queries ask for information from the tables associated with features or from stand alone tables associated with the GIS. Attributes can be numeric values, text strings, Boolean values (i.e., true or false), or dates. This kind of query is similar to a query made to any database; however, when using a GIS, the answers (i.e., the features related to the records selected by the process) are highlighted on the map as well as in the table.

The answers to spatial queries are derived directly from the location of features on a map. Information about the proximity of one parcel to other parcels or other kinds of features, such as roads, is not contained in an attribute table but is easily learned using a spatial query. For example, you could ask if one or more features are located within a certain distance of other features, are contained by another feature, intersect other features, or possess another of the relationships defined by spatial operators.

GIS is powerful because it can use both attribute and spatial queries to get answers with far less effort or answer questions that would not be practical to answer using any other method.




*The Select by Attributes dialog box in ArcMap helps build queries by presenting the values and SQL operators available in the underlying database. This query uses LIKE to capture all the records with an OWNER_NAME that contains the string 'CHAVEZ'.*

### Building a Basic Query

All basic queries have three parts: a source, a filter, and a relationship. This is true of both attribute and spatial queries. The source can be a table or feature class. The filter can be an attribute value or a shape or feature. The relationship between the source and the filter is based on logical, comparison, or spatial operators.

When creating a query, identify which table or feature class will contain the information that answers your question. If the question is, What parcels have a specific commercial zoning? an attribute table for parcel features that contains a field for zoning would likely be a source.

The filter identifies what is different about the desired items, whether those items are table records or features. In the commercial zoning example, that characteristic would be the code C-3, which identifies the commercial zone of interest.

The relationship between the source and filter does the work of finding the record or features. Continuing with the example, the relationship would be that the zoning field contains the value C-3 so the relationship would be "equals" or =.

Relationships are defined using operators. Comparison and logical operators are applied to attribute queries. Comparison operators include =, <>, >, >=, <, and <=. LIKE, AND, OR, and NOT are logical operators. In contrast to the relatively short list of operators for attribute queries, there are more than a dozen types of spatial operators. Intersect, Are Within a Distance Of, Contain, and Are Contained By are some of the most common and useful ones. Spatial queries performed using Select by Location deal with vector data and use a shape as a filter and its relationship with features in the source layer to answer a question.


*Spatial queries use the shape and location of one set of features to select another set of features. This illustration shows how a spatial query finds the point, line, or polygon features that intersect with polygon features in another layer.*

## Using Operators

When selecting by attribute, LIKE and NOT are often used to compare text strings and match patterns, often employing wildcards. Wildcards can replace one character or a group of characters that are unknown. The character used depends on the data source being queried. For personal geodatabases, use a question mark (?) for a single character and an asterisk (*) for a group of characters. For shapefiles, ArcSDE geodatabase feature classes, and other types of data, use an underscore (_) to replace a single unknown character and a percentage sign (%) to replace a group of characters. ArcMap will detect the type of database being queried and adjust the wildcard characters available through the Select by Attribute dialog box.

LIKE is a good operator for finding text strings that contain variant spellings or possibly misspellings, of a text string. Rather than using an equal sign followed by the search term enclosed in quotes, use LIKE and enclose the search term and a wildcard character with quotes.

Like the characters used for wildcards, the syntax used when querying dates depends on the underlying database. ArcMap automatically writes the proper syntax when you double-click on a date value in the Unique Values list of the Select by Attribute dialog box.

The choice of spatial operator (i.e., the relationship tested by the query) depends on the types of features that will be used for the source and filter.

## Answering More Complex Questions

To meet multiple search criteria, several attribute queries can be combined using logical operators (such as AND, OR, LIKE, and NOT) to find records based on several criteria in two or more attribute fields.

Remember that OR is the far more flexible and inclusive operator. When using AND, both conditions must be true to return records. For queries that use OR, only one condition must be true to return records.

Ordinarily, queries are evaluated from left to right. However, any portion of the query enclosed in parentheses is evaluated first. The order of operations can be important both in obtaining a valid answer to the question being asked and in optimizing the way a query runs.

A single query such as "LOT_SIZE" >= 1 AND "LOT_SIZE" <= 2 AND "SLOPE" < 5 could be used to locate parcels with lots between one and two acres in size that have a slope of less than 5 percent.

For more complex spatial queries, subqueries can be used to sieve data. The results of one query can be used as the basis for additional queries related to the currently selected features, either selecting from those features, adding to those features, or removing features from the selected set. These operations work in much the same way as AND and OR operators by creating subsets that will be the basis for additional selections.

## Working with Both Query Types

Although attribute and spatial queries can work together in locating the desired information, because they are entered in ArcMap in different dialog boxes (Select by Attribute, Select by Location), these two different kinds of queries must be posed separately.

To expand the previous example (and narrow the search), the desired parcels must have sold within the last year, be zoned C-3, and be located within five miles of a specific parcel in addition to being between one and two acres in size with a slope of less than 5 percent. The date sold and zoning information are also stored in the attribute table but identifying the parcels within five miles of the subject parcel will require a spatial query.

Limiting the parcel search to those that fall into the five-mile buffer around the subject parcel will eliminate many records, so that query is performed first. Using the features selected by location, an attribute query that evaluates the sale date to limit the selection, then the zoning, lot size, and slope will identify features that fulfill all criteria.

## Conclusion

Whether the question to answer is simple or complex, break down the question being asked into its query components—source, filter, and relationship—and arrange those components in the order that correctly and efficiently answers that question. Understanding the data distribution in a data source will also help you understand how to best order operations to minimize the number of records that must be searched. For more help on building queries, refer to the ArcGIS Desktop Help Online (available at resources.esri.com/arcgisdesktop) and search for the topic "SQL reference."

# Why GIS Is a Great Investment for Government

## New book on decision support and public policy

Learn how GIS technology can help government officials streamline operations and deliver smart solutions that save time and money in *GIS for Decision Support and Public Policy Making.* This new book from ESRI Press describes how GIS can be integrated into many aspects of governing and policy making.

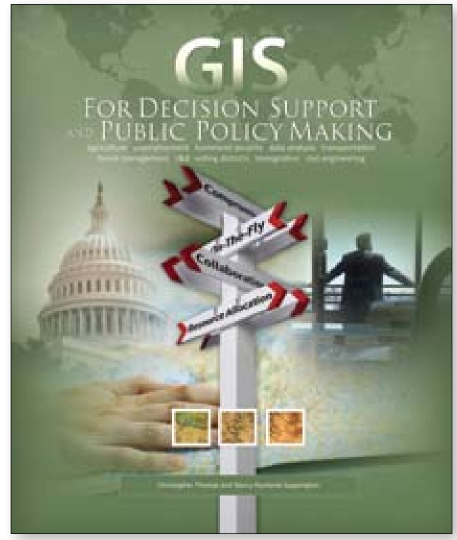
Book chapters cover topics such as how to use GIS for making budget-related decisions, reaching compromises, allocating resources, supporting policies, and making decisions. The book provides 27 examples of how government organizations used GIS software to analyze and map data, collect information from the field, and publish geographic information services on the Web.

For example, GIS was used to find the best locations for fire stations in Denver, Colorado; prioritize waterline repairs and construction in Houston, Texas; track code compliance problems in Pasadena, California; analyze natural disaster risk areas in British Columbia, Canada; and map immunization data in Utah to improve health care for children.

"Oftentimes, community leaders are recipients of the by-products of GIS such as reports, maps, and analysis," said the book's coauthor Christopher Thomas. "The book shows how GIS directly supports management and elected officials in developing and implementing decisions and public policy—not as a by-product but rather as an integral part of the process."

Exercises included at the end of each chapter underscore the importance of including GIS methodology in the decision-making process. The book's return on investment (ROI) matrix illustrates how the use of GIS in these projects paid off in terms of saving time and money, increasing efficiency and accuracy, generating additional revenue, enhancing communication and collaboration, automating workflows, and improving allocation of resources.

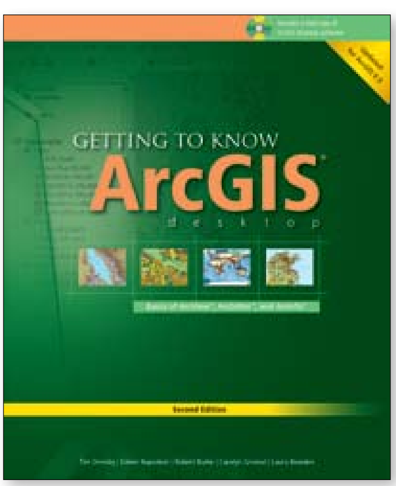
"Geography and GIS can provide enormous benefits to an organization including providing the right kind of support to make accurate and informed decisions," ESRI president Jack Dangermond wrote in the book's foreword. "Government officials are under increasing pressure to make the right choices while minding the budget and delivering value at the same time. You'll find many examples




in this book about how they are doing just that." ESRI Press, 2009, 204 pp., ISBN: 978-1-58948-231-9

# New Edition of Best-Selling GIS Text

## Workbook covers ArcGIS 9.3 release




*Getting to Know ArcGIS Desktop: Basics of ArcView, ArcEditor, and ArcInfo,* an ESRI Press best seller for the last seven years, has been revised so exercises are compatible with ArcGIS 9.3.

This workbook requires no previous knowledge of GIS concepts or software. It supplies an overview of GIS and introduces the features and functionality of ArcMap and ArcCatalog, the core products in ArcGIS Desktop. The remaining sections of the book cover displaying data, getting information from features, analyzing the relationships between features, creating and editing data, presenting data, and modeling data.

Step-by-step exercises, accompanied by numerous screen captures, teach the basics of tasks such as building and editing spatial databases, mapmaking, and performing spatial analyses. Each exercise focuses on specific GIS tasks or skills. While exercises later in the book build skills learned in earlier chapters, the maps and data for each exercise are supplied on an accompanying CD so exercises may be worked independently. *Getting to Know ArcGIS Desktop: Basics of ArcView, ArcEditor, and ArcInfo,* Second Edition can be used as a classroom text or self-study guide. Exercise data and a fully functional, 180-day trial copy of ArcView 9.3 are also provided with the book. ESRI Press, 2008, 600 pp., ISBN: 978-1-58948-210-4

*ESRI Support Services has nearly doubled the number of technical experts within the last year.*

# It's Just Easier Now

## New support resources

Support Services is your primary resource for troubleshooting any technical issues you encounter with ESRI software. ESRI has new resources for getting you solutions quickly. More staff, extended hours, online resource centers, and a new Customer Care portal make it easier to get the support you need to be more successful with ESRI products.

### More people to take phone calls and respond to e-mails immediately

As ESRI customers have changed the way they use software to reach their goals, Support Services has added to its talented team. Within the last year, ESRI Support Services has nearly doubled the number of technical experts available. Continued aggressive recruitment ensures the staff will grow with the increasing number of users.

### Extended hours of operation that better match when you need support

With the addition of the East Coast Support Center, located in Charlotte, North Carolina, along with ESRI's global headquarters in Redlands, California, Support Services now takes questions from 5:00 a.m. to 5:00 p.m. (Pacific time) Monday through Friday.

### Easier access to useful information

ESRI's new online resource centers (resources.esri.com) make it much easier to locate information that can point you in the right direction when you encounter a problem. These centers are organized by topic or product, providing one place to access information and support. Go to these resource centers to quickly find samples, online instructional content, tutorials, hosted content, developer resources, and ESRI blogs. Resource centers can be launched directly from the software.

### Bugs Online database

In addition to resource centers, the Support Center now publishes a searchable database containing known ESRI software issues. Save lots of time and aggravation by visiting Bugs Online at support.esri.com. Use this database to determine if your problem is a known software bug.

### New Customer Care portal

After contacting ESRI Support Services, it is now easier to track the incidents and bugs you have reported. Managing and monitoring all ESRI account and support information are easy for an organization's primary contact person using the new Customer Care portal (customers.esri.com). Primary contacts are the people in an organization who are involved in the business relationship with ESRI and have access to the Customer Care portal. Through this portal, primary contacts for an organization can keep up with specific software and maintenance information, account activity (e.g., order history, shipment tracking, User Conference passes, primary contact information), technical support history of all incident and bug information, and


*The Customer Care portal is an excellent tool to use to manage and monitor ESRI account information.*

training information on classroom and Virtual Campus courses.

### Service Pack Announcements

Before the release of every service pack, Service Pack Announcements on the ESRI Support site will help you better prepare for future upgrades and projects more effectively by using this list of issues targeted to be fixed in the release. (See "More Information on Service Packs" on page 7 of the Winter 2009 issue of *ArcUser.*) You can give feedback on the listed issues through a dedicated forum available with the announcement.

More changes planned for the coming year are planned to improve your experience with ESRI Support Services. Log on to the Support Center and send feedback to guide ESRI on how to best serve your needs.

# A Day in the Life

## Working in software development at ESRI

Many people are drawn to ESRI because of its outstanding technical reputation, its unique culture, and the opportunity to work with smart, creative people in an open, collaborative environment. In this interview, Nawajish Noman, who is a lead product engineer on the ArcGIS Spatial Analyst and Geostatistical Analyst teams, talks about what it's like to work in software development at ESRI. He is part of the Geoprocessing and Analysis Group and develops analysis functions and tools for ArcGIS.

*Nawajish Noman*

**Q: How did you end up at ESRI?**

**Noman:** That's kind of an interesting question. I started as a GIS user. I'm a water resources engineer, and I was using GIS to solve water resources problems like floodplain delineation and flood management. I liked the way I could use GIS so much that after doing my Ph.D. in water resources, I knew I wanted to work at ESRI and ended up here. I've been working here for more than seven years, building GIS tools for GIS and water resources professionals.

**Q: Describe what you do here and what a typical day is like.**

**Noman:** Before we develop the software, we actually design it. Depending on where we are in the development cycle, we might spend more time initially in designing. But as we move forward, we start testing the functionality. As we find problems, we submit bugs, get them fixed, then test again. Eventually, we start to document it. Finally, once everything is done, we release the software. In between, we do other things such as answer users' questions and create applications like sample models and sample tools. As a product engineer, you get to do a lot of different things on a daily basis.

**Q: What do you find challenging about your job?**

**Noman:** The most interesting part about my job is that it's really dynamic—that's what keeps me here. No two days are the same. I come in and start my day, and sometimes it's totally different than what it was yesterday. Every day we face new challenges. We solve new problems, and it's changing every day.

**Q: What kinds of skills are needed for your team?**

**Noman:** We need and use different skills to develop our software's new functionality. Our developers come from different technical backgrounds but are very analytical by nature. Once you have those skills, we'll use your background or experience in many different ways.

**Q: What do you feel ESRI offers its employees that sets it apart from similar organizations?**

**Noman:** ESRI is a unique organization in many different ways. First, if you start with the technology, it is the software. Our software actually changes people's lives because it can be used to make better decisions, which eventually affects somebody else's life down the line. That is the technology part of it. If you think about the work environment, it is also unique because it is very friendly. Let me put it this way: we are very professional in an informal environment—we work like friends and colleagues with nice software.

**Q: What's the work environment like in your group?**

**Noman:** We work in teams, which means we develop software as a team. It's important that team spirit is high and cooperation is strong. Like any team in software development at ESRI, our group also has great team spirit and we work closely together. It is a great environment.

**Q: What do you like about living in the Redlands area?**

**Noman:** Redlands is very close to Los Angeles, so you get all the benefits of a big town without living in a big town. For example, you can drive an hour and see the ocean, or you can go and see the mountains. Or, if you want to see Disneyland or Universal Studios, that's not far either. So, from Redlands, you can go in any direction and enjoy your life the way you want. That's a good thing about Redlands and living in this area.

**Q: Any closing thoughts?**

**Noman:** ESRI is a great company. That's first and foremost. If you are a GIS professional and really want to change the way GIS is done and make it better, this is a great place for you. We welcome you here. If you work here, you'll enjoy it and you'll help us make things better.

# **Flex**–ible Web Site Serves More Data about Schools

## Federal data clearinghouse upgrades site

An ArcGIS Server-based Web site that was implemented using the ArcGIS API for Flex makes data from a federal education data clearinghouse more accessible to researchers, policy makers, administrators, teachers, businesses, parents, and students.

The National Center for Education Statistics (NCES), a division of the United States Department of Education, launched the site in October 2008. The School District Demographics Systems (SDDS) Web site (nces.ed.gov/surveys/sdds/map00.asp) provides direct access to data on individual schools and school districts and related demographic data.

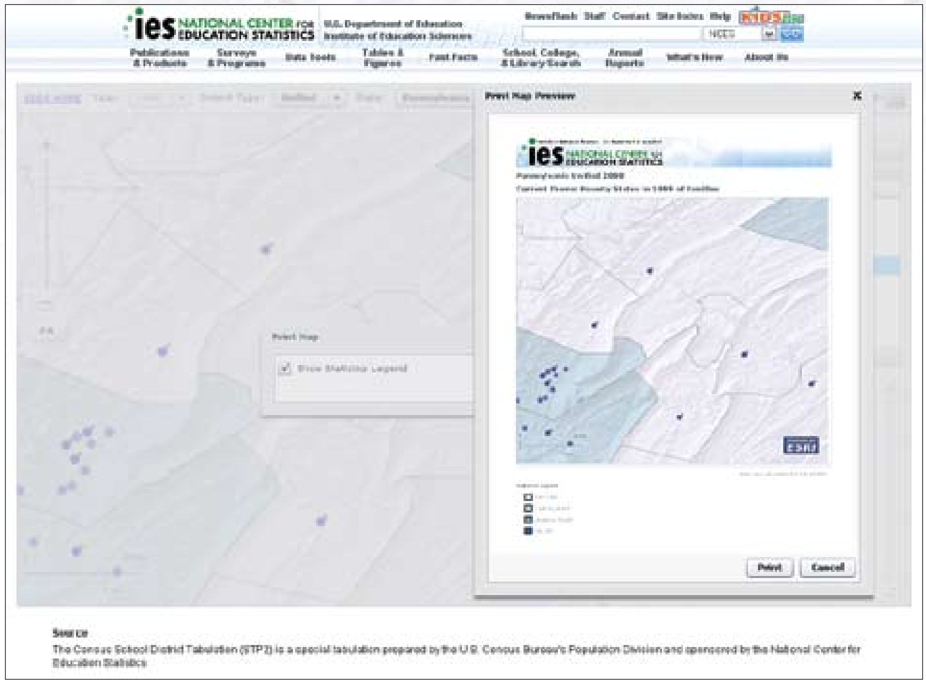
This site replaces a previous ArcIMS-based site. The new SDDS Web site supplies quicker access to more data and allows users to compare data among districts over time. Visitors to the site can view more detailed information at different scales.

"ArcIMS met our needs in 2000, but we wanted to increase the speed of the site and our data uploads," said Tai Phan, program director of the Library Statistics Program at NCES. "Implementing the new technology of Adobe Flex eased customization for programmers and increased map-loading speed for end users. A huge benefit is that we can use this technology for four to five years without having to go through another customization.

"The transition was smooth, and the number of hits to the site have increased each month," said Phan. "Before the transition, we averaged 21,000 hits to Map Viewer, and by November, we had 73,000 hits. The speed and features of the new mapping technology contribute to this increase."

At the state level, the new site supplies choropleth maps that display demographic data such as population, housing, race, income, and education levels for each school district. At the district level, users can explore data on school district boundaries and individual schools. Users can also find data about revenue and expenditure sources that show how a school district is funded and what programs the district supports (e.g., Gifted and Talented, Bilingual Education, Vocational Education).

NCES and the U.S. Census Bureau began collaborating on SDDS during the 1990 Census with the Census Mapping Project. During the decennial Census 2000, the Census Bureau provided 90 percent of the data and state governments provided the remainder to develop school district maps. This work led to a complete set of nationwide school district and demographic maps. The yearly addition of demographic data from the American Community Survey and better mapping tools have enhanced the functionality of the site.




*Users choose the print function for a printer-friendly map of poverty levels of selected school districts, overlaid by schools in each district.*

However, NCES determined it needed to better manage its geodatabase and improve the SDDS site's mapping tool, Map Viewer. Upgrading to ArcGIS Server increased the speed and flexibility of Map Viewer. ESRI business partner Blue Raster LLC worked with NCES to develop the ArcGIS API for Flex version of Map Viewer.

NCES will continue adding data to the site as it becomes available including the 2007 American Community Survey and the 2010 Census. The division already shares information with the Department of Homeland Security. In the future, tools that will assist police and fire stations when responding to emergencies will be added. One tool will allow first responders to quickly determine the distance to a school and the number of students and faculty that are on the campus.

For more information on NCES's implementation of ArcGIS Server, contact Phan, program director, at Tai.Phan@ed.gov. To learn more about the ArcGIS API for Flex API, take the ESRI free Web training seminar *Building Rich Internet Applications with ArcGIS API for Flex.*

## Worldwide Forum for GIS Educators

### Many resources available at Education Community Web site

Launched at the Education User Conference (EdUC) in 2007, ESRI's Education Community Web site provides a forum for sharing lessons, events, and ideas. A blog, interactive maps, and a large database of GIS education materials are prominent features. Collaborative tools such as the GIS Education calendar, Community Atlas, and the University Programs registry all leverage user-supplied content to create a rich, dynamic environment for GIS education. Visit the site at edcommunity.esri.com.

# Resources for Professionals, Scholars, and Students

## GIS bibliography tops 75,000 entries

One of the world's largest online repositories for information about geographic information science (GIScience) and GIS technology is available at no charge from the ESRI Web site.

The ESRI GIS Bibliography, on the ESRI Education and Training Web site (training.esri.com/library), recently surpassed 75,000 entries. The easy-to-search site is an excellent resource for scholars, scientists, geographers, cartographers, and professionals in a wide range of industries. These references not only direct users to published materials but also identify experts in geospatial research and technology.

The bibliography references more than 1,000 sources—mostly journals, magazines, conference proceedings, and books. Though mainly abstracts, the bibliography also includes links to articles, conference papers, book chapters, and theses in PDF format. It encompasses many fields and industries from marine sciences and the environment to defense, petroleum, and health.

For every year since 1993, the bibliography contains all abstracts and submitted papers for the ESRI International User Conference. Many abstracts from the Association of American Geographers' annual meetings are also posted. Citations from hundreds of journals, such as the *International Journal of Geographic Information Science, Cartographica,* and *Applied Geography,* are available as well as material unavailable anywhere else online.

Dr. Duane F. Marble, professor emeritus of geography at Ohio State University, began compiling the bibliography in the late 1980s. Marble saw the need for a more comprehensive public resource. When Marble retired from his academic position, ESRI became the curator of the bibliography.

Mirroring the growth of GIS itself, the bibliography continues to grow steadily. On average, about 2,000 entries are added each month. "Although there are other specialized GIS bibliographies, the ESRI resource covers a broad span of disciplines, applications, and theory as well as representing the history of GIS," said Marble. "The global reach of GIS is also clear. During the early years, North America, Europe, and Australia dominated the contributions, but now we see significant input from other regions such as Asia—specifically China."

The ESRI Library staff in Redlands, California, works with Marble and continues updating bibliography content and maintaining the Web site as a free service to the GIS and GIScience community.

# New **ESRI** Higher Education Head

## Director brings extensive expertise and experience

Promoting spatial literacy among students in all disciplines is one of the main goals of ESRI's new director of higher education. Dr. Michael Gould, who joined ESRI in December 2008, will also concentrate on supporting the implementation of GIS not only across academic departments but also as a tool for improving campus operations such as facilities management and green initiatives.

"When GIS is used for problem solving, a student analyzes data within its spatial context, which allows for more informed decision making," said Gould. "GIS is used on campuses for teaching and research in traditional spatial disciplines, such as geography and planning, but there are also significant benefits from using geospatial technology in wider areas such as business and public health departments."

Gould brings 20 years of experience in teaching and research to ESRI. He began his career after earning a Ph.D. in geography (GIS) from the National Center for Geographic Information and Analysis (NCGIA), University at Buffalo, New York. Recently, he served as an interdisciplinary professor of information systems and was a cocreator of an Erasmus Mundus-funded geospatial technologies master's program at Universitat Jaume I, Castellón, Spain. Gould has been involved in creating spatial data infrastructures (SDI); researching standards-based interoperability with the Open Geospatial Consortium, Inc. (OGC), and developing geospatial Web services.

In addition to academic and research pursuits, Gould has worked as a GIS advisor to government agencies in the European Union (EU), businesses (including ESRI and Microsoft), and nonprofit organizations. He is an active member of the Association of Geographic Information Laboratories in Europe (AGILE) and recently completed a two-year term as the chairperson of its management board. He was also nominated by the Spanish government to serve as an expert on a series of research projects with the EU including Infrastructure for Spatial Information in Europe (INSPIRE).

"Solving the problems of the twenty-first century requires a populace that's adept at creating and using geospatial technology. Michael Gould is a thought leader in the international GIS community who will help foster the open sharing of information and new forms of cooperation and collaboration with the education community," said ESRI president Jack Dangermond.

# New ESRI Authorized Instructors

The Authorized Training Program (ATP) is pleased to acknowledge the newest class of ESRI Authorized Instructors. These candidates have passed all ATP requirements and have been granted authorization to teach the specified ESRI courses within the United States. These instructors join a network of more than 400 ESRI Authorized Instructors. For a complete listing of ESRI Authorized Instructors in your area, please visit www.esri.com/atp; contact the ATP by e-mail at atp@esri.com; or call 909-793-2853, ext. 1-2111.

Abbreviations for each course authorization are listed in the table. The course authorizations shown with each instructor listed indicate only the most recent authorization(s) received by that instructor. Visit the ATP Web site for complete information on all authorizations held by an instructor.

### Course Abbreviations

| | |
|---|---|
| AAV | Advanced ArcView 3.x |
| AG1 | Introduction to ArcGIS I (for ArcGIS 9) |
| AG2 | Introduction to ArcGIS II (for ArcGIS 9) |
| AGD1 | ArcGIS Desktop I |
| AGD2 | ArcGIS Desktop II |
| AGD3 | ArcGIS Desktop III |
| AGSA | Working with ArcGIS Spatial Analyst |
| AIMS | Introduction to ArcIMS |
| AV3 | Introduction to ArcView (3.x) |
| BGDB | Building Geodatabases |
| IAGS | Introduction to ArcGIS Server |
| LGAD | Learning GIS Using ArcGIS Desktop |
| MGDB | Introduction to the Multiuser Geodatabase |
| PAO | Introduction to Programming ArcObjects with VBA |
| PAOJ | Introduction to Programming ArcObjects Using the Java Platform |
| PAON | Introduction to Programming ArcObjects Using the Microsoft .NET Framework |
| PYTH | Geoprocessing Scripts Using Python |

**Alaska**
Peter Hickman
Geoapps Inc.
North Pole, AK
907-750-1641
geoapps@gci.net
AGD2, AGD3

Michael Knapp
Blue Skies Solutions LLC
Anchorage, AK
907-230-4372
mknapp@blueskiessolutions.net
AGD2

**Arizona**
Lewis "Cody" Cohn
Pima County, Arizona
Tucson, AZ
520-740-6328
lewis.cohn@dot.pima.gov
AGD2, AGD3

Michele Mattix
Sedona, AZ
480-298-8877
michele@geomattix.com
AGD2, AGD3

Thomas McConnell
McConnell & Associates
Tucson, AZ
520-579-8438
gisprof@gmail.com
AGD2, AGD3

Brad Tatham
Independent Consultant
Tucson, AZ
520-971-7624
gistrainer@gmail.com
AGD2, AGD3

**Arkansas**
Richard Pierce
Act Geospatial Inc.
North Little Rock, AR
501-771-2985
rpierce@actgeospatial.com
AG1

**California**
Ronald Abelon
California Department of Transportation
Sacramento, CA
916-227-5265
ron_abelon@dot.ca.gov
AGSA

Andres Abeyta
IGIS Technologies Inc.
San Diego, CA
619-640-2330, ext. 114
abeyta@igist.com
AGD2, AGD3

Michelle Boivin
Technology Associates International Corporation
Carlsbad, CA
760-763-6691
mboivin@taic.net
AGD2

Eileen Goff
Geomorph Information Systems, LLC
San Diego, CA
619-218-6463
egoff@geomorphis.com
AGD1, AGD2, LGAD

John Johnson
GIS Workshop
Encinitas, CA
760-889-8606
john@gisws.com
AGD2, AGD3

Lisa Pierce
Redlands, CA
909-553-4710
l.pierce@verizon.net
AGD2

Chris Quinn
Cypress College
Cypress, CA
714-484-7000
cquinn@cypresscollege.edu
AGD1

Linda Richards
Artisan Global LLC
Los Angeles, CA
213-841-3448
linda@artisanglobal.com
AGD1, AGD2

Robert Slobodian
California State University, Fresno
Fresno, CA
559-278-8458
rslobodian@csufresno.edu
AGD2, AGD3

Arthur Stackhouse
VESTRA Resources, Inc.
Redding, CA
530-223-2585
art@vestra.com
AGD2, AGD3

Paul Van Zuyle
Penfield & Smith Engineers
Santa Barbara, CA
805-963-9532
pvz@penfieldsmith.com
AGD2

**Colorado**
R. J. Kern
GIS Learning LLC
Lakewood, CO
303-474-0983
rj@gislearning.com
AGD1

**Delaware**
Deborah Sullivan
Dover, DE
302-739-9021
Deborah.Sullivan@state.de.us
AGD2, AGD3

**Florida**
Miguel Garriga
Geographic Systems LLC
Altamonte Springs, FL
321-279-6019
mgarriga@geographicsystems.com
AGD1, AGD2, AGD3

Kevin Gray
SAIC
Melbourne, FL
321-751-3244
kevin.a.gray@saic.com
AGD2

James Judge
City of West Palm Beach
GIS Coordinator
West Palm Beach, FL
561-822-1226
jjudge@wpb.org
AGD2

David Kelly
Forest Resource Consulting Inc.
Tallahassee, FL
850-668-4022
frcgis@earthlink.net
AGD3

Charlee Nichols
Marion County
Ocala, FL
352-671-8802
charlee.nichols@marioncountyfl.org
AGD2

Suzanne Roulston-Doty
GIS Associates Inc.
Gainesville, FL
352-384-1465
sdoty@gis-associates.com
AGD1, AGD2, AGD3

Carol Walker
County of Polk
Bartow, FL
863-534-4783
carolwalker@polk-county.net
AG1

**Georgia**
Randall Carlton, PMP, MCP
Keck & Wood, Inc.
Duluth, GA
706-296-7959
rcarlton@keckwood.com
AGD2

Tripp Corbin
Keck & Wood, Inc.
Duluth, GA
678-417-4013
tcorbin@keckwood.com
AGD3

Joshua Eller
Booz Allen Hamilton Inc.
Atlanta, GA
719-648-8251
eller_joshua@bah.com
AGD2

**Illinois**
Soomee Cha Kong
The Sidwell Company
Saint Charles, IL
630-549-1000
soomeecha@yahoo.com
AGD2

Steven Di Naso
Eastern Illinois University
Charleston, IL
217-581-6248
sdinaso@eiu.edu
AGD1, LGAD

**Indiana**
Keri Brennan
The Schneider Corp.
Indianapolis, IN
317-826-7390
kbrennan@schneidercorp.com
AGD2, AGD3

Melissa Brenneman
TopoWorks
Noblesville, IN
317-776-9996
Melissa@topoworks.com
AGD2

Irvin Goldblatt
State of Indiana
Indianapolis, IN
317-233-3410
IGOLDBLA@idem.in.gov
AGD2, AGD3

**Iowa**
Brent Estrem
City of Ankeny
Ankeny, IA
515-965-6402
bestrem@ankenyiowa.gov
AGD1, AGD2

**Kansas**
Scott Rice
City of Olathe
Olathe, KS
913-971-6642
srice@olatheks.org
AGD2

Ken Wilkerson
GISEdge Inc.
Wichita, KS
316-928-4724
ken@gisedge.com
AGD2, AGD3

**Kentucky**
Therese Cunningham Dowdy
University of Kentucky
Lexington, KY
859-257-3000
tdowdy@bae.uky.edu
AGSA, AGD2, AGD3

Jeffrey Levy
University of Kentucky
Geography Dept.
Lexington, KY
859-323-0618
jeff.levy@uky.edu
AGD2

**Louisiana**
Alaa Shams
Louisiana State University
School of the Coast & Environment
Louisiana Geographic Information Center (LAGIC)
Baton Rouge, LA
225-578-8980
ashams@lsu.edu
AGD2, AGD3

**Maryland**
Shannon Rose
AEGIS/McCrone Inc.
Centreville, MD
410-758-2237
srose@mccrone-inc.com
AGD2

Kate Sontag
KCI Technologies Inc.
Hunt Valley, MD
410-316-7804
kate.sontag@kci.com
AGD2

**Massachusetts**
Michael Olkin
Town of Amherst
Amherst, MA
413-259-3247
olkinm@amherstma.gov
AGD2

Rachael Ouellet
Tighe & Bond Inc.
Worcester, MA
508-471-9607
rlouellet@tighebond.com
AGD2

**Minnesota**
Terese Rowekamp
Rowekamp Associates
Bloomington, MN
952-882-4776
trowekamp@rowekamp.com
AGD2, AGD3

Jennifer Ward
Pro-West & Associates, Inc.
Walker, MN
218-547-3374
jward@prowestgis.com
AGD2

**Mississippi**
Gunnar Olson
Mississippi State University
Geosystems Research Institute
Starkville, MS
662-325-3704
gunnar@gri.msstate.edu
AGD2

Chuck Patrick
Jackson State University
Jackson, MS
601-979-5913
cpatrick@jsums.edu
AGD1, AGD2

Nel Ruffin
Mississippi State University
Geosystems Research Institute
Starkville, MS
662-325-7459
nr19@msstate.edu
AGD1, AGD2

Scott Samson
Mississippi State University
Starkville, MS
662-325-9491
scotts@gri.msstate.edu
AGD2, AGD3

**Missouri**
Kristin Collins
City of Kansas City
Kansas City, MO
816-513-3635
kristin_collins@kcmo.org
AGD2

Laura Estabrooks
City of Columbia
Columbia, MO
573-874-6382
lae@gocolumbiamo.com
AGD2

Heather Milton, GISP
URS Corp.
St. Louis, MO
314-368-5596
heather_milton@urscorp.com
AGD2, AGD3

Anthony Spicci
State of Missouri Department of Conservation
Columbia, MO
573-882-9909
Tony.Spicci@mdc.mo.gov
AGD1, AGD2, AGD3, LGAD

**Montana**
Lydia Bailey
Montana Fish, Wildlife & Parks
Helena, MT
406-444-5365
lbailey@mt.gov
AGD2

Van Shelhamer
Geoessentials Inc.
Bozeman, MT
406-579-3367
Vhamer@aol.com
AGD2

Kenneth Wall
Geodata Services Inc.
Missoula, MT
406-532-3239
kwall@geodataservicesinc.com
AGD1

**Nebraska**
Sonja Sebree
Kirkham Michael & Associates Inc.
Omaha, NE
402-343-3932
ssebree@kirkham.com
AGD2, AGD3

**New Hampshire**
Katie Jacques
Microdesk
Bedford, NH
800-336-3375
kjacques@microdesk.com
AGD2

**New Mexico**
Julie Coonrod
University of New Mexico
Albuquerque, NM
505-277-3233
jcoonrod@unm.edu
AGD2

Tim Obrien
Earth Touch Solutions LLC
Albuquerque, NM
505-379-9190
earthtouch@earthlink.net
AGD2

Karl Seitz
USDOI Bureau of Indian Affairs
Albuquerque, NM
505-328-5252
backra43@hotmail.com
AGSA

**New York**
John Fox
L-3 Communications
Lake George, NY
518-668-5838
john.r.fox@L-3com.com
AGD2

Stephen D. Smith
Cornell University
Institute for Resource Information Sciences
Ithaca, NY
607-255-0803
sds3@cornell.edu
AGD1, AGD2

**North Carolina**
Joseph Forrest
Resource Geoservices LLC
Efland, NC
919-732-8416
jforrest@resourcegeoservices.com
AGD2

Krzysztof Koltyk
County of Moore
Carthage, NC
910-947-1078
ckoltyk@moorecountync.gov
AGD2, AGD3

Scott Wade
East Carolina University
Geography Dept.
Greenville, NC
252-328-6029
wades@ecu.edu
AGD2

**Ohio**
Melanie White
City of Dayton
Dayton, OH
937-333-2031
melanie.white@cityofdayton.org
AGD2

**Oklahoma**
Nancy Pinkerton
ConocoPhillips
Bartlesville, OK
918-661-7904
nancy.pinkerton@conocophillips.com
AGD2, AGD3

Joseph Wallis
Samson Investment Company
Tulsa, OK
918-591-1047
hwallis@samson.com
AGD3

**Oregon**
John Schaeffer
Juniper GIS Services Inc.
Bend, OR
541-389-6225
john@junipergis.com
AGD1

**Pennsylvania**
William Chappell
PoconoGIS
Saylorsburg, PA
610-871-0472
bill@poconogis.com
AGD2

Carrie Wengert
CET Engineering Services
Harrisburg, PA
717-541-0622
cwengert@cet-inc.com
AGD2

**Rhode Island**
Aimee Mandeville
University of Rhode Island
Kingston, RI
401-874-2930
aimee@edc.uri.edu
AGD2

**South Carolina**
Christopher Bradshaw
Bradshaw Consulting Services Inc.
Aiken, SC
803-641-0960
cbradshaw@bcs-gis.com
AGD2

Christopher Harvey
Bradshaw Consulting Services Inc.
Aiken, SC
803-641-0960
charvey@bcs-gis.com
AG2, AGD3

Michael Rink
Geo On The Go LLC
Summerville, SC
843-277-0524
mike@GeoOnTheGo.com
AGD2, AGD3

Amy Wright Webber
Appalachian Council of Governments
Greenville, SC
864-241-4634
webber@scacog.org
AGD2, AGD3

**Tennessee**
Randal Hale
North River Geographic Systems Inc.
Chattanooga, TN
423-653-3611
rjhale@northrivergeographic.com
AGD2

Neill Jobe
Geo Jobe GIS Consulting
Nashville, TN
615-883-0085
njobe@geo-jobe.com
AGD2, AGD3

Brian Waldron
University of Memphis
Center for Partnerships in GIS
Memphis, TN
901-678-3283
bwaldron@memphis.edu
AG1

**Texas**
Jeff Barnett
TeachMeGIS
Houston, TX
713-278-7883
jeff.barnett@TeachMeGIS.com
AGD1, AGD2, AGD3

Justin Cure, GISP
City of Longview
Longview, TX
903-237-2700
jcure@ci.longview.tx.us
AGD1, AGD2 , AGD3

Christina Dischinger
County of Harris
Public Health & Environmental Service
Houston, TX
713-439-6288
cdischinger@hcphes.org
AGD2, AGD3

Jennifer Harrison
TeachMeGIS
Houston, TX
713-278-7883
Jennifer.Harrison@TeachMeGIS..com
AGD1, AGD2, AGD3

Ingrid Hartz
IPH Consulting Inc.
Houston, TX
713-408-7025
ingrid@iphconsulting.com
AGD2

Leslie Morgan
TeachMeGIS
Houston, TX
713-278-7883
Leslie.Morgan@TeachMeGIS.com
AGD2, AGD3

Larry Nierth
City of Houston
Planning & Development Dept.
Houston, TX
713-837-7893
larry.nierth@cityofhouston.net
AGD1, AGD2

Beni Patel
Tessellations Inc.
The Woodlands, TX
936-321-1998
beni@tessellations.us
AGD2, AGD3

Tracy Rijken
TeachMeGIS
Houston, TX
713-278-7883
Tracy.Rijken@TeachMeGIS.com
AGD1, AGD2, AGD3

Amy Grones Snelgrove
Texas A&M University
College Station, TX
979-845-4476
amy-snelgrove@tamu.edu
AGD2

Karen Steede Terry, GISP
TeachMeGIS
Houston, TX
713-278-7883
Karen.Terry@teachmegis.com
AGD2, AGD3

**Utah**
Gordon Douglass
State of Utah
Salt Lake City, UT
801-537-9189
gdouglass@utah.gov
AGD2

Bob Nagel
State of Utah
Automated Geographic Reference Center
Salt Lake City, UT
801-538-3291
bnagel@utah.gov
AGD2, AGD3

**Virginia**
Christopher Knouss
MITRE Corporation
McLean, VA
240-606-5075
cknouss@mitre.org
AGD2, AGD3

Denis Roose
Edgetech America Inc.
Glen Allen, VA
888-334-3832
droose@edgetech-us.com
AGD2, AGD3

William Shuart
Virginia Commonwealth University
Center for Environmental Studies
Richmond, VA
804-827-0150
wshuart@vcu.edu
AGD2

**Washington**
Bruce Kessler
Kessler GIS
Cheney, WA
509-235-5500
bruce@kesslergis.com
AGD2, AGD3

Mary Ullrich
King County
Seattle, WA
206-684-1789
mary.ullrich@kingcounty.gov
AGD1, AGD2

Cheryl Wilder
King County
Seattle, WA
206-263-5220
cheryl.wilder@kingcounty.gov
AGD1, AGD2, AGD3

**Wisconsin**
Tom McClintock
University of Wisconsin
Land Information & Computer Graphics
Madison, WI
608-263-5534
tlmcclin@wisc.edu
AGD1, AGD2, AGD3

Gina Siroy
USDA Forest Service Region 9
Milwaukee, WI
414-297-3499
gsiroy@fs.fed.us
AGD3

**Wyoming**
Margo Berendsen
University of Wyoming
Laramie, WY
307-766-2751
meh@uwyo.edu
AGD2, AGD3

# Combining Math, GIS, and Community Service

*Obenhaus and Vidaurre test water at one of the newly built wells in Haiti.*

# Teacher inspires students to use GIS to solve real problems

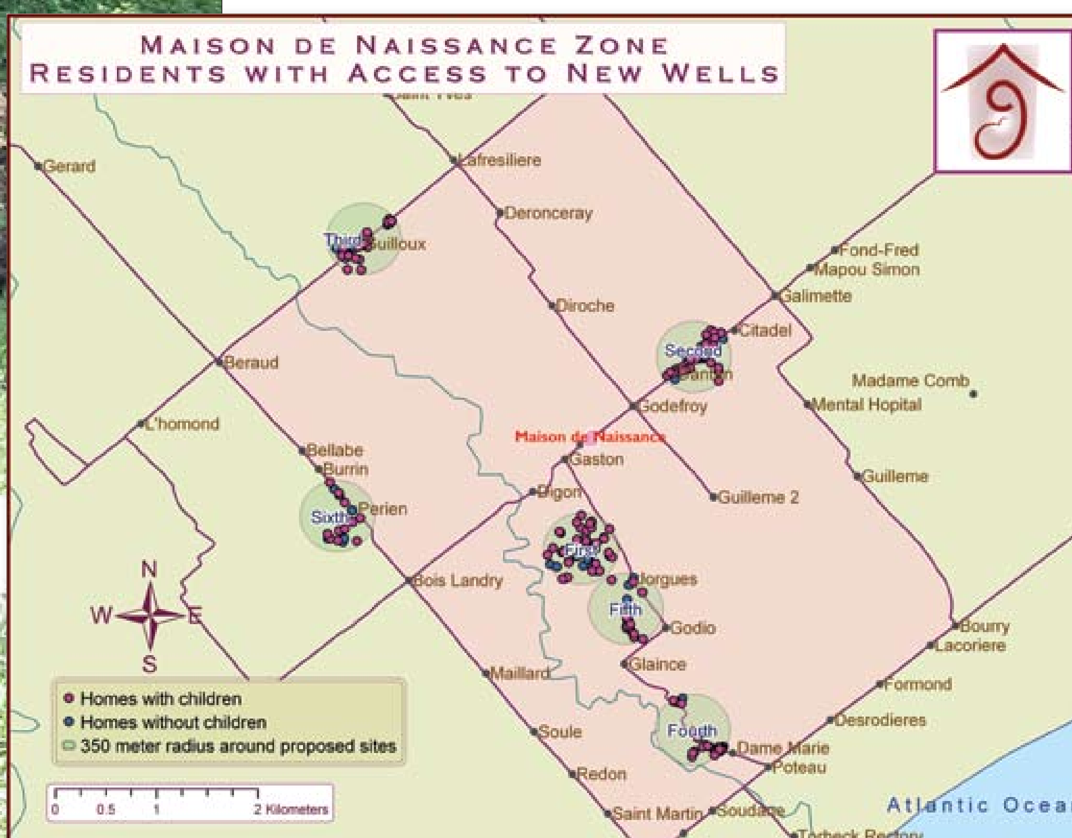
Steve Obenhaus, a math teacher at Olathe North High School in Olathe, Kansas, has proved that you do not need extensive GIS training to effectively and meaningfully integrate geospatial technologies into a high school curriculum.

Integrating GIS in secondary curricula is a relatively new concept. Finding an approach that will hold students' short- and long-term interest can be difficult. Obenhaus has succeeded in incorporating GIS in his math courses and has helped his students produce high-quality GIS projects.

Students in the school's Distinguished Scholars program spend one hour per day during their senior year completing a senior project. This program offers students individualized lesson plans in a specific discipline. Since Obenhaus and another teacher introduced GIS to the school, student scholars in geoscience, biotechnology, and math have used GIS in their projects.

Obenhaus has a simple approach: ask a question about something that is bothering you and use GIS combined with math to answer the question. "I teach math, which is more of a tool than a subject," explained Obenhaus. "By combining GIS and math, students use both tools to answer spatial questions about the world. Only with GIS can they quickly perform multiple analytic functions and see spatial patterns that are not apparent with a graph or table."

*Continued on page 68*




*With help from a Kansas GIS professional, Vidaurre used ArcView to identify the highest clusters of children without access to clean water. With this information, she located six new wells where they would benefit the greatest number of children.*

# Combining Math, GIS, and Community Service

*Continued from page 67*

His official GIS training was a two-week institute at a local university. Most of his GIS training has been informal. "I realized that GIS is very flexible. I played around with it and realized it could be used in so many ways in my classes. You don't need six months of training to have students do simple projects," said Obenhaus.

When questions arise that he cannot answer, Obenhaus challenges students to figure out the answers before he does using ArcView online help. When questions cannot be answered using online help, Obenhaus calls on city and county GIS professionals who help. Some local professionals come into class. According to Obenhaus, students really enjoy learning from people who use GIS in their career.

In Obenhaus' classroom, the first step in creating a project is having the students think spatially about a problem. He says that coming up with a question is the easy part, because most problems have a spatial component. "I learn from others' examples, so when I find good data online, I think about a question students can answer with it. When I see how professionals solve problems, I start to see the possibilities of what can be done in my own community." This year, his students are collecting data about the water quality of a local stream before, during, and after a construction project. They are using GIS to look at changes not only along the length of the stream but also over time.

His next step is helping students figure out a problem-solving approach that combines math and GIS. Students learn the basic functions of ArcView during in-class lessons taken from the ESRI Press book series *Our World GIS Education.* These textbooks include interdisciplinary GIS lesson plans for different academic levels. Once students have a basic understanding of GIS, they stop working on prepared lessons and start working on independent projects. In these projects, they ask a spatial question and find the data needed to answer it.

Obenhaus gives students the necessary tools, GIS training, a question, and an approach to problem solving. Then he lets students figure out a solution. "They pick up GIS really quickly when they play with ArcView during their own project, learning by trial and error," said Obenhaus.

There is a common thread in his students' projects. In addition to answering a spatial question, students have followed Obenhaus' philanthropic example and worked on projects that serve communities, whether these communities or local or half a world away.

Obenhaus and his wife do volunteer work for a maternity and neonatal clinic, Maison de Naissance, in a rural area of southern Haiti. The clinic's mission is to decrease maternal and infant mortality rates in an area with extreme poverty.

*In developing countries, children often do most of the water collection. Closer access to safe water not only improves their health but also gives them greater opportunities to attend school.*

Water-based diarrheal diseases are the leading cause of infant mortality in the developing world. When the clinic received funding to build wells to give more families access to clean water sources, the clinic director asked Obenhaus if he and his students could locate these wells.

He agreed. When he began the project, Obenhaus had little knowledge of water testing and locating water sources. He began by asking a water analyst how to test water quality. He then traveled to Haiti with donated supplies and trained Haitians to test the water.

This work was assisted by one of Obenhaus' students, Elizabeth Vidaurre, who went on to develop her own related project. A distinguished math scholar at Olathe North High School, Vidaurre combined her math and GIS skills in a senior project for determining how to select well locations that would benefit the greatest number of children in need.

The water testing results, combined with the clinic's records on the number of children and where they live, were the basis for Vidaurre's research project. "We had two unique data layers that no one else had," said Obenhaus, who had students use ArcView to create basemaps from the data.

"At first I thought it would be like playing a computer game, but it was serious work to use GIS," said Vidaurre. "It's a tool that helps you solve real problems. I could have done the project without GIS, but it would have taken much longer to analyze data and would not have been as accurate."

With help from a Kansas GIS professional, Vidaurre used ArcView to create buffers around the homes of families living more than 350 meters from a clean water source. With this information, she analyzed where the highest clusters of children without access to clean water were located.

The project was successful, but it took a few attempts to get it right. Obenhaus and Vidaurre worked together to find a quantitative approach for locating wells. Vidaurre ran chi-square tests to first determine if access to a deep-drilled well was an advantage. She found there was an advantage: the data showed a strong correlation between the presence of *E. coli* and hand-dug wells and open springs. By finding the best location for six wells, 1,180 children in need would have access to clean water.

"Because of learning GIS, writing the paper, and presenting the results, I feel more prepared for life," said Vidaurre. "As a high school senior, I was networking with CEOs to fund-raise for my project. It helped me feel more confident as an intern working at a health systems IT company." The CEO and others were impressed by her project and, during her summer internship, had Vidaurre present ways GIS could benefit their company.



Presentations about her work in Haiti not only resulted in donations for her project but made her a recipient of the Spirit of Philanthropy Youth award from the Association of Fundraising Professionals (AFP).

After graduation, Obenhaus brought Vidaurre to Haiti to see the results of her work. Looking back on the experience Vidaurre said, "I have traveled in Latin America, but I had never seen a country that was so underdeveloped. I saw babies who were malnourished and kids with bellies bloated from worms. It was important to me to see the places I mapped and meet people. It wasn't just about wells, because personal experiences and new relationships remain most important to me."

Obenhaus keeps Vidaurre, who is now a junior at the University of Rochester, up-to-date on the latest work done at Maison de Naissance. Difficulties in gathering data have made it difficult to show a decline in rates of pediatric water-related diseases. Nonetheless, Dr. Stan Shaffer, director of Maison de Naissance, sees the work of Obenhaus and his students as beneficial.

"In poor communities, such as the villages of rural Haiti, it is critically important that health needs be carefully defined so that critical resources can be targeted for their highest impact," said Shaffer. "Steve and students such as Liz are demonstrating how mapping is an essential tool for organizing health information. You wouldn't attempt microbiology without a microscope, so it's not surprising that Steve Obenhaus says that we shouldn't attempt community health work without good maps."

Obenhaus' students continue working on the wells project. For example, they found that not only were new wells needed, but old wells had to be repaired. The latest student projects look at other health-related issues such as what happens to the quality of water once it leaves a well. Students found that just because water is clean at its source does not mean people drink clean water, so they are now trying to figure out how collection and storage methods affect water quality.

Obenhaus, who is clearly an inspiration to his students, downplays his influence. "It's easy to look good when you are surrounded by smart kids who work really hard to make a difference in the world," said Obenhaus. "To me, this is not work, it's fun." In 2007, Obenhaus was selected at the state level to receive a Presidential Award for Excellence in Mathematics and Science Teaching.

Obenhaus' teaching approach can be replicated for advanced placement human geography, math, community service programs, and other courses, both traditional and nontraditional. For more information, contact Steve Obenhaus at sobenhauson@olatheschools.com.

## ESRI Corporate Headquarters:

**380 New York Street**
**Redlands, CA 92373-8100 USA**
Tel.: 909-793-2853
Fax: 909-793-5953
E-mail: info@esri.com
Web: www.esri.com

ESRI Technical Support
Tel.: 888-377-4575
Fax: 909-792-0960
E-mail: support@esri.com
Web: www.esri.com/support

Online Discussion Forums
ESRI-L: esri-l@esri.com
ARCVIEW-L:
arcview-l@esri.com
Web: www.esri.com/forums
FTP: ftp.esri.com

ESRI Desktop Order Center
and Software Information
Tel.: 1-800-447-9778 (USA only)
Fax: 909-307-3049
E-mail: info@esri.com

ESRI Customer Service
Toll Free
Tel.: 888-377-4575
Fax: 909-307-3082
E-mail: service@esri.com
Web: www.esri.com/customerservice

ESRI Store
Web: www.esri.com/store

ESRI Developer Network
Web: edn.esri.com

### U.S. Regional Offices:

Boston
Danvers, MA
Tel.: 978-777-4543
Fax: 978-777-8476

California
Redlands, CA
Tel.: 909-793-2853,
ext. 1-1906
Fax: 909-307-3025

Charlotte
Charlotte, NC
Tel.: 704-541-9810
Fax: 704-541-7620

Denver
Broomfield, CO
Tel.: 303-449-7779
Fax: 303-449-8830

Minneapolis
St. Paul, MN
Tel.: 651-454-0600
Fax: 651-454-0705

Olympia
Olympia, WA
Tel.: 360-754-4727
Fax: 360-943-6910

Philadelphia
Chesterbrook, PA
Tel.: 610-644-3374
Fax: 610-644-3379

San Antonio
San Antonio, TX
Tel.: 210-499-1044
Fax: 210-499-4112

St. Louis
St. Charles, MO
Tel.: 636-949-6620
Fax: 636-949-6735

Washington, D.C.
Vienna, VA
Tel.: 703-506-9515
Fax: 703-506-9514

### ESRI International Distributors:

ESRI Australia Pty. Ltd.
Brisbane
Tel.: 617-3218-4100
E-mail: connect@esriaustralia.com.au
Web: www.esriaustralia.com.au

ESRI BeLux
Wemmel, Belgium
Tel.: 32-2-460-7480
E-mail: info@esribelux.com
Web: www.esribelux.com

ESRI Bulgaria Ltd.
Sofia
Tel.: 359-2-964-0850
E-mail: info@esribulgaria.com
Web: www.esribulgaria.com

ESRI Canada Limited
Toronto, Ontario
Tel.: 416-441-6035
E-mail: info@esricanada.com
Web: www.esricanada.com

ESRI Chile S.A.
Santiago
Tel.: 56-2-481-9000
E-mail: info@esri-chile.com
Web: www.esri-chile.com

ESRI China (Beijing) Limited
Beijing
Tel.: 86-10-6554-1618
E-mail: info@esrichina-bj.cn
Web: www.esrichina-bj.cn

ESRI China (Hong Kong) Limited
Hong Kong
Tel.: 852-2730-6883
E-mail: info@esrichina-hk.com
Web: www.esrichina-hk.com

ESRI Eastern Africa Ltd.
Nairobi, Kenya
Tel.: 254-20-271-3630
E-mail: sales@esriea.co.ke
Web: www.esriea.co.ke

ESRI España
Madrid, Spain
Tel.: 34-91-559-4375
E-mail: info@esri-es.com
Web: www.esri.es

ESRI Finland Oy
Espoo
Tel.: 358-207-435-435
E-mail: info@esri-finland.com
Web: www.esri-finland.com

ESRI France
Meudon
Tel.: 33-1-46-23-6060
E-mail: info@esrifrance.fr
Web: www.esrifrance.fr

ESRI Geoinformatik GmbH
Kranzberg, Germany
Tel.: 49-8166-677-0
E-mail: info@esri-germany.de
Web: www.esri-germany.de

ESRI Hungary
Budapest
Tel.: 361-428-8040
E-mail: esrihu@esrihu.hu
Web: www.esrihu.hu

NIIT-GIS Ltd. (ESRI India)
New Delhi
Tel.: 91-11-4669-4666
E-mail: info@esriindia.com
Web: www.esriindia.com

ESRI Italia
Rome, Italy
Tel.: 39-06-406-961
E-mail: info@esriitalia.it
Web: www.esriitalia.it

ESRI Japan Corporation
Tokyo
Tel.: 81-3-3222-3941
E-mail: esri_general@esrij.com
Web: www.esrij.com

ESRI Korea, Inc.
Seoul
Tel.: 82-2-2025-6700
E-mail: info@esrikr.com
Web: www.esrikr.com

ESRI Lebanon sal
Beirut
Tel.: 961-1-844944
E-mail: info@esrilebanon.com
Web: www.esrilebanon.com

ESRI Muscat CO LLC
Muscat, Oman
Tel.: 968-246-93723
E-mail: info@esrimuscat.com
Web: www.esrimuscat.com

ESRI Nederland B.V.
Rotterdam
Tel.: 31-10-217-0700
E-mail: gisinfo@esri.nl
Web: www.esri.nl

ESRI Northeast Africa
Cairo, Egypt
Tel.: 202-2516-7485
E-mail: info@esrinea.com
Web: www.esrinea.com

ESRI Polska
Warsaw, Poland
Tel.: 48-22-390-4700
E-mail: esripol@esripolska.com.pl
Web: www.esripolska.com.pl

ESRI Portugal
Lisbon
Tel.: 351-2-1-781-6640
E-mail: market@esri-portugal.pt
Web: www.esri-portugal.pt

ESRI Romania S.R.L.
Bucharest
Tel.: 40-21-231-1422
E-mail: esri@esriro.ro
Web: www.esriro.ro

ESRI South Asia Pte. Ltd.
Singapore
Tel.: 65-6742-8622
E-mail: lwong@esrisa.com
Web: www.esrisa.com

ESRI S-GROUP Sverige AB
Gävle, Sweden
Tel.: 46-771-98-48-00
E-mail: info@esri-sgroup.se
Web: www.esri-sgroup.se

ESRI (Thailand) Co. Ltd.
Bangkok
Tel.: 66-2-678-0707
E-mail: krairop.l@cdg.co.th
Web: www.esrith.com

ESRI Turkey
Ankara
Tel.: 90-312-235-6491
E-mail: mtankut@esriturkey.com.tr
Web: www.esriturkey.com.tr

ESRI (UK) Ltd.
Aylesbury
Tel.: 44-1296-745-500
E-mail: info@esriuk.com
Web: www.esriuk.com

Grupo ESRI de Venezuela, C.A.
Caracas
Tel.: 58-212-285-9394
E-mail: joaquin@esriven.com
Web: www.esriven.com

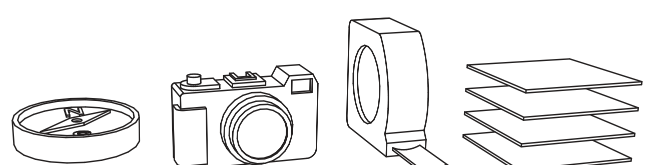
ESRI also has distributors in other countries around the world. For more information, contact ESRI (tel.: 909-793-2853, ext. 1-1235; fax: 909-307-3070).


# NEW!
# GMS-2 Pro

All of the innovative features of the GMS-2 plus the power and convenience of integrated laser measurement! This groundbreaking combination of imaging and measuring technology brings unmatched productivity to any GIS application.

Simply aim and shoot to map offset points. No more manual offsets or connecting external devices. Snap a photo and tap points on the image to measure height or width of features. Store these values as attributes. Data collection is faster, safer and more accurate.

The GMS-2 Pro. The best just got better.



Electronic Compass | Digital Camera | Electronic Distance Measurement | GIS Data

TOPCON
It's time.

800.443.4567 • www.topconpositioning.com

ESRI
380 New York Street
Redlands, CA 92373-8100 USA

PRSRT STD
US POSTAGE
**PAID**
ESRI