Winter 2010

ArcUser

The Magazine for ESRI Software Users

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Geomedicine

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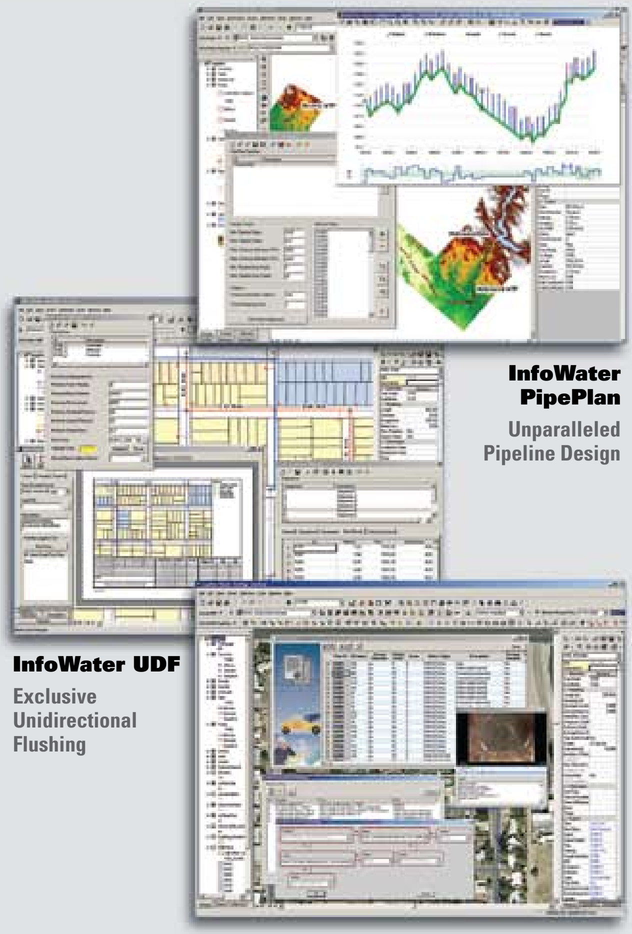

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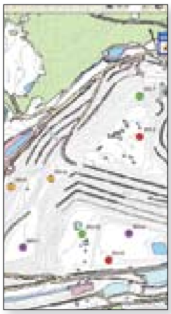
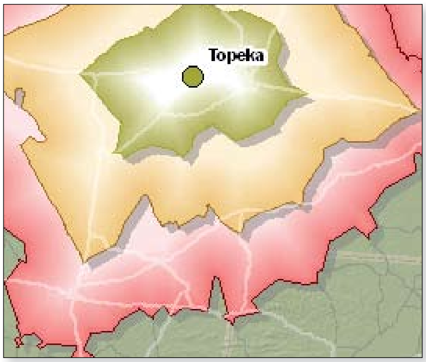
FEATURE



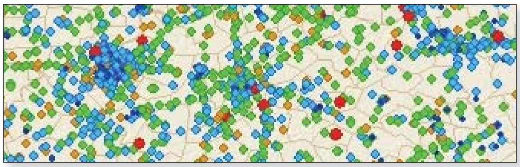
FOCUS

Geomedicine



SPECIAL SECTION

All about Geodatabase Versioning



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The Role of Geographic Information

Fifty years ago, most people had a different relationship with geographic information. That relationship was based almost entirely on maps. A map was something that fell out of the middle of the latest issue of *National Geographic* magazine or lived in the car's glove box (if you managed to refold it) or was tacked up on a classroom wall.

In the intervening decades—thanks to GIS—the use of geographic information has expanded exponentially. Now it so permeates our world that its use has become remarkably integrated into everyday life. Geospatial technologies are working behind the scenes improving the generation and distribution of energy, the production of food, and the safeguarding of water supplies. Mapping is an expected feature of cell phone applications and Web sites. These technologies get us to our destinations, help emergency responders find us, and increasingly, give us a broader view of our world.

This issue of *ArcUser* highlights the Worldmapper project, a mapping Web site that has the potential to tremendously expand our appreciation of the world. Its 696 maps employ equal area cartograms to explore data on demographics, transportation, military spending, and biodiversity, to name just a few of the myriad of aspects of the world the site addresses. Its maps and data files, which cover 200 territories, make current and complex data accessible and comprehensible.

Making information more available and usable is improving the operations of organizations such as the San Diego Port Authority. By employing a geographic approach, the organization has decreased the time needed for accessing critical information about the 6,000-acre facility from hours to minutes. Ready access to this information has streamlined operations and improved decision making.

ESRI global health and human services marketing manager Bill Davenhall describes the need for ready access to critical information of a more personal nature. Davenhall advocates the inclusion of place history in the medical records of individuals. This record of where a person lives and has lived will allow the rich stores of environmental information that are being collected to be included in the risk factors considered by physicians diagnosing and treating patients. Making space for place in medical histories is just another way geographic information will improve our lives and our world.

Monica Pratt
ArcUser Editor

editor's page

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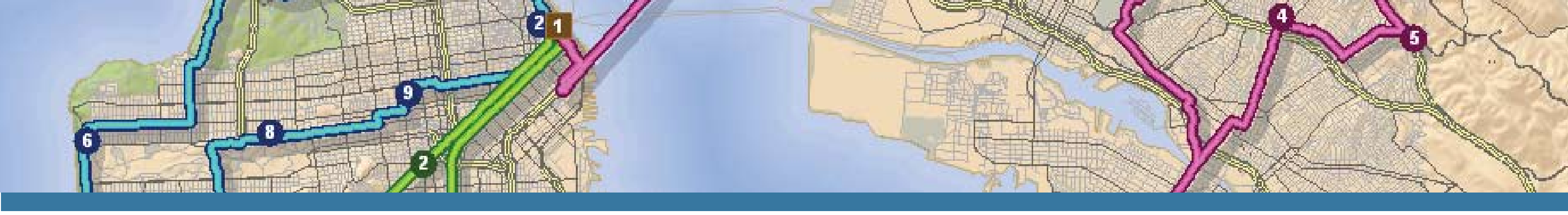
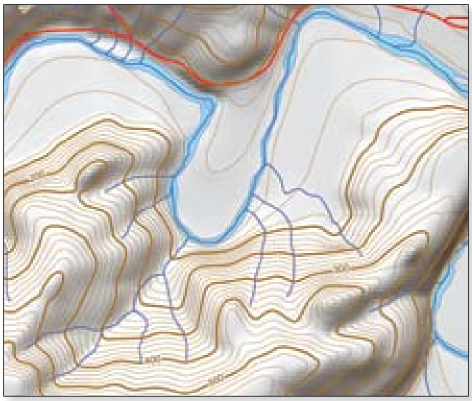
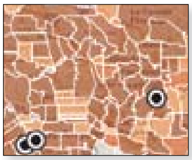


DEPARTMENTS



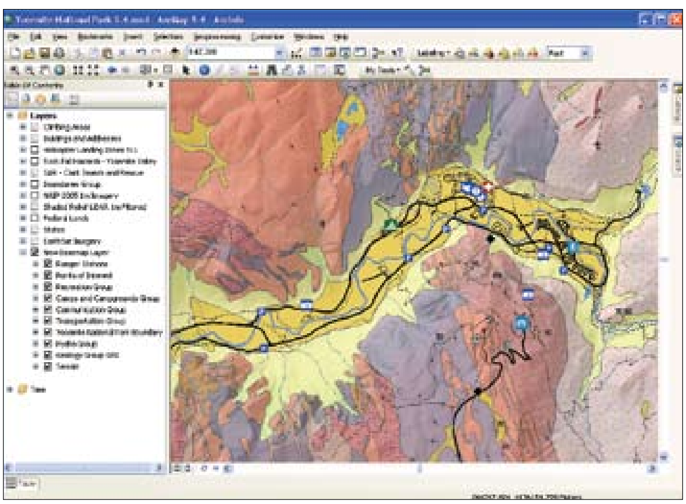


Get GIS Work Done Faster

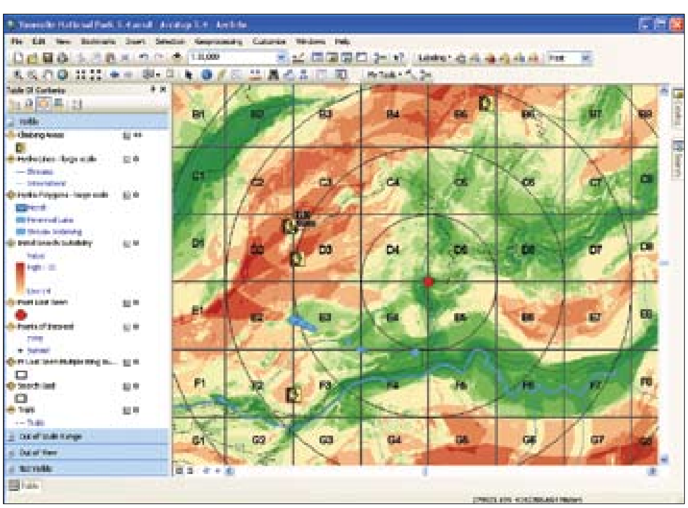
ArcGIS 9.4 is focused on productivity

Work More Efficiently in ArcGIS Desktop
Faster and more responsive drawing performance speeds up the data authoring process. In previous releases, ArcMap redrew each layer sequentially when updating the view. The new basemap layer in 9.4 enables continuous, fast redraw. Dockable windows can automatically hide and a new Catalog window is embedded in ArcMap. Easy access to the most commonly used geoprocessing tools and background execution of geoprocessing operations significantly improves productivity.

Interactively Sketch and Design Maps
Design maps using interactive sketch and design tools. Streamline your map production workflows with dynamic layout text elements (e.g., title, date, page number), as well as map templates. These templates can be used for the production of high-quality maps for both the desktop and Web. This release also includes new geoprocessing tools for multiscale map creation and to support layouts with multiple pages for making map books, including PDFs. Optimized map services support cartographic representations and Maplex labeling. The new compact cache format facilitates creation and management of large map caches and saves disk space.



Basemap layers redraw more quickly in ArcGIS 9.4.



The table of contents supports multiple views.

Manage and Create Data More Easily
The new Catalog window in ArcMap simplifies project management and collaboration. New query layers in ArcGIS access all data (including spatial data) stored in relational databases via standard SQL. Open API access to the file geodatabase at ArcGIS 9.4 makes data management and creation easier.

Improved Editing in 2D and 3D
Easier access to common editing tools in ArcMap, ArcScene, and ArcGlobe, as well as new template-based editing, are delivered in ArcGIS 9.4. A customizable on-screen palette of features is available for desktop and Web clients. Edit the geodatabase over the Web with the new Feature Editing Service. The new customizable ArcGIS Mobile application for mobile and Tablet PC devices allows fast field editing and on-site design work.

New Reporting Capabilities
With the series of predefined templates supplied with ArcGIS 9.4, it is easier to make nicely formatted reports. Once created, these reports can be saved so they can be reexecuted with a different selected set.

Analysis and Modeling
Enhanced customization capabilities provide access to all analysis tools. With 9.4, geoprocessing tools and models can be dragged and dropped onto a toolbar. New tools improve the geoprocessing framework: ModelBuilder support for undo/redo, iteration, and ToolTips as well as improved map algebra with Python support.

- New geoprocessing tools, such as Fuzzy Overlay and Fuzzy Reclassify, improve site selection and suitability modeling and location-allocation modeling of network datasets.
- New classification tools make image collection and the evaluation of training samples easier.
- New ecological sampling design tools accommodate user-defined spatial criteria.

New types of graphs make visualizing results more meaningful and intuitive.

Improved 3D and 4D GIS Environment
Visualize, manage, analyze, and share data in both 3D and 4D with ArcGIS 9.4. This release evolves the 3D GIS environment with editing in 3D and 3D analysis in ArcScene and ArcGlobe as well as templates and best practices for creating virtual cities. ArcGIS 9.4 is now time aware. Display and animate temporal datasets as well as publish and query temporal map services.

Tighter Integration of Imagery with ArcGIS
Fast, dynamic raster display and on-the-fly processing and mosaicking improve the integration of imagery with GIS for better analysis and display. ArcGIS 9.4 also provides stronger ArcGIS Web API support for advanced imagery visualization.

Manage Licenses More Easily
Check out shared ArcGIS 9.4 licenses more easily on a different computer (for fieldwork, remote offices, etc.) for temporary use in a controlled environment.

Enhanced Configurable Web Mapping Applications
A new out-of-the-box configurable Web mapping application for ArcGIS Server delivers a rich user experience on top of powerful ArcGIS Server services. Nondevelopers can create good-looking, fast, scalable, and fully functional GIS applications for Web users.

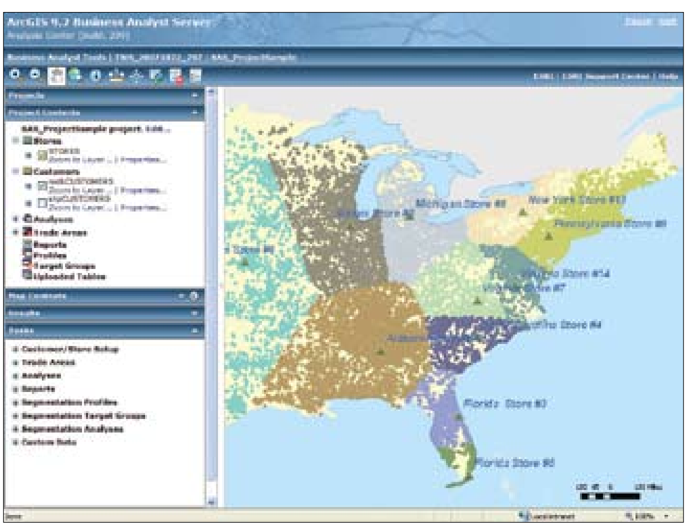
Simplified Mobile Project Management
Out-of-the-box ArcGIS Mobile projects on laptops and tablet-based PCs streamline deployment and expand GIS to vehicle-based workflows. Field data collection benefits from streaming GPS, photo attachments, and location tracking for all ArcGIS Mobile applications. Administrators can quickly configure mobile projects using the new Mobile Project Center that simplifies project deployment. Developers can easily extend mobile applications with custom tasks and data sources using the ArcGIS Mobile SDK.

View videos about ArcGIS 9.4 at www.esri.com/whatscoming.

Simplify Reporting with ESRI Business Analyst Server

Customizable templates for faster report delivery

New sharing and usability enhancements in ESRI Business Analyst Server speed report delivery and help users conduct more precise business analysis. ESRI Business Analyst Server is the first complete enterprise solution for business.



Businesses obtain true representations of their trade areas by color shading their customers according to the stores they visit.

Custom report templates created with ESRI Business Analyst Desktop Advanced Editor can be uploaded to Business Analyst Server and published to the repository where Business Analyst Server client applications can consume generated reports using Business Analyst Desktop. Developers can also consume the report output in XML format to supply data for application features.

Business Analyst Server now includes a Select By Attributes tool that allows users to select features in a layer based on an attribute value. Now users can select all the ZIP Codes in a given market where households have a median household income greater than some dollar amount or select all the stores with certain characteristics (a specified number of parking lots, for example).

Other sharing and usability enhancements include simplified XML output and access to the ArcGIS Online map database. Business Analyst Server also features a Create Store/Customer layer using a table of x,y coordinates. Users whose data is already geocoded can take advantage of x,y values directly and include latitude/longitude value pairs for the points in DBF, XLS, and XLSX files.

Business Analyst Server also includes updates to ESRI demographics and consumer spending data, Directory of Major Malls (DMM) shopping centers, *info*USA business listings and locations, Tele Atlas streets, and address points.

For more information on ESRI Business Analyst Server, visit www.esri.com/baserver.

The Site Evaluation workflow template is a fully functioning example of the consistent and repeatable business processes that can be created with Workflow Framework.

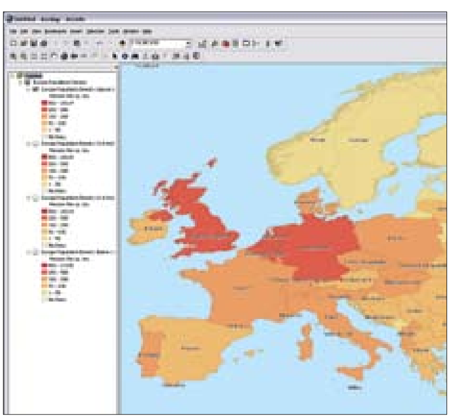
An Abundance of Data

Easy access to basemaps and reference layers

GIS users now have more sources of high-quality, well-documented data and maps. In addition to the familiar ESRI Data & Maps, many basemaps and specialty maps are available online and from ArcGIS Data Appliance.

ESRI Data & Maps

For many years, ESRI has shipped ESRI Data & Maps with ESRI software. This collection of DVDs provides basemaps and specialty maps



Users can download individual data layers from the most current version of ESRI Data & Maps from ArcGIS Online for immediate use.

that let users become immediately productive. ESRI Data & Maps contains map data at many scales of geography. All vector data is provided in Smart Data Compression (SDC) format, and most raster data is in JPEG 2000 format. The entire dataset can be read directly from DVDs. The HTML-based help system contains information about ESRI Data & Maps and StreetMap North America, including a complete list of the redistribution rights for each dataset.

General basemap information is available for the world, North America, and Europe. The significant basemap layers included are boundaries, cities, rivers, and roads. In addition, where possible, demographic data is provided for subnational boundaries such as states, counties, or their equivalents. Additionally, commercial data from Tele Atlas, AND International Publishers NV, WorldSat, EarthSat, Michael Bauer Research, World Wildlife Fund, SIGSA, and ESRI, as well as all levels of U.S. Census geography and ZIP Code data, is included.

Each ESRI Data & Maps dataset includes a metadata (.xml) file containing complete documentation and an ArcGIS layer (.lyr) file for symbolizing the dataset in ArcGIS. Each SDC file also includes a projection (.prj) file that supplies the coordinate system information used by ArcGIS. Map document (.mxd), published map (.pmf) files, and group layer (.lyr) files are included for all geographic areas to provide symbolized maps of the datasets.

A version of ESRI Data & Maps basemaps and reference layers has been created that is optimized for ArcGIS Server and is available upon request. *ESRI Data & Maps for ArcGIS Server* is a free DVD with map caches and/or globe caches and an ArcGIS Server configuration file. Map document (.mxd) and globe document (.3dd) files are included for use in creating the map and globe services on ArcGIS Server.

ESRI StreetMap Premium

ESRI StreetMap Premium, an enhanced street dataset, works with ArcGIS for optimal geocoding and routing and high-quality cartographic display for North America and Europe. The ready-to-use datasets are based on data from NAVTEQ or Tele Atlas. The licensing model for StreetMap Premium allows users to get data customized by geographic area and mapping use. For more information on ESRI StreetMap Premium, visit www.esri.com/streetmap.

ArcGIS Online

In addition to obtaining ESRI Data & Maps DVDs, users can download individual data layers from the most current version of ESRI Data & Maps from ArcGIS Online for immediate use. ArcGIS Online supplies free maps, imagery, and tasks in addition to premium content available by subscription. ArcGIS Online standard map services are available at no cost for internal and noncommercial external use in ArcGIS 9.3 Service Pack 1 and 9.3.1 and with ArcGIS Web Mapping APIs. Using ArcGIS Online standard map services for commercial purposes or using ArcGIS Online premium map services requires the purchase of an annual subscription.

In addition to free access to world imagery, world street maps, and world physical and topographic maps through standard map services, ArcGIS Online Sharing, an application currently in beta, allows users to upload and share data and maps. This central repository of GIS content includes maps, layers, and tools from ESRI as well as users who have joined the ArcGIS Online community. The free membership system lets users create interest groups, join groups, and control access to data being shared.

ArcGIS Data Appliance

For organizations that need reliable access to high-performance data and tasks behind their firewalls, ArcGIS Data Appliance supplies imagery, street map, and topographic data on the preconfigured network storage device. This data has been updated and coverage has been expanded to ensure users have access to the most efficient and consistent data they need for their critical projects.

The latest release of ArcGIS Data Appliance includes significantly enhanced map offerings. ESRI's imagery offerings have now been combined into one unique service on ArcGIS Data Appliance. All the previously available offerings, including World IKONOS Cities Imagery, World Imagery, and USA Prime Imagery, have been merged and blended with new high-resolution imagery for Great Britain and other countries. The best data from each service was used to provide the optimal vintage, resolution, and coverage for the new imagery collection.

World Street Map features improved cartography and building footprints. North American and European maps have updated 2009 data from Tele Atlas and AND. Coverage of the European street map has been expanded for the largest scale (1:5,000 meters), and the international maps now include detailed street maps for Japan, Hong Kong, Thailand, and Colombia.

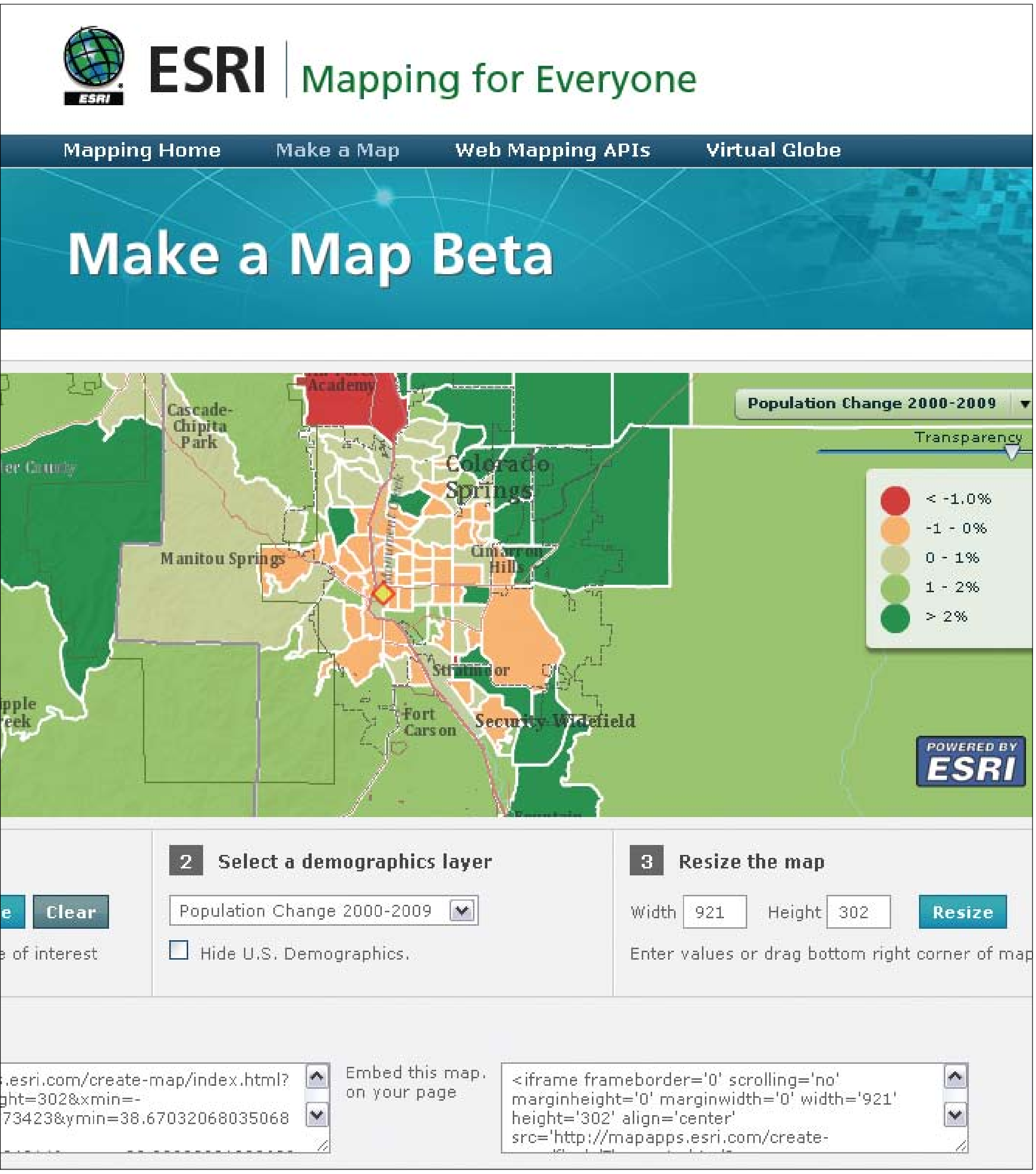
In the latest release, all ArcGIS Data Appliance maps have been migrated to a new tiling scheme, the Web Mercator projection, that uses 256 x 256 pixel tiles with refined scales. Because this is the same tiling scheme used by Bing Maps and Google Maps, users can more easily create mashups with other Web maps. As all ESRI maps will now be in the same projection, this migration will also simplify caching decisions for ArcGIS users.

Because ArcGIS Data Appliance powers ArcGIS Online, all these updates and enhancements are also available from ArcGIS Online.

Explore Web Mapping

Simple mapping, many resources available from site

Mapping for Everyone (www.esri.com/mappingforeveryone), a Web site launched by ESRI, helps visitors explore interactive mapping using free tools.



Get started immediately by creating and sharing an interactive Web map.

Make a Map—This section features a simple, interactive Web mapping application that shows seven U.S. demographic layers: median household income, population change between 2000 and 2009, median home value, population density per square mile, unemployment rate, average household size, and median age.

Simply zoom in to an area of interest, select a demographic layer, and resize the map as desired. Share the map by embedding or linking. Copy and paste the automatically generated HTML in a Web page or link to a map by e-mailing it or adding it to Twitter, Facebook, or other social media.

Web Mapping APIs—Develop rich, interactive mapping applications using JavaScript, Flex, or Silverlight Web mapping APIs. This Web page includes step-by-step instructions for installing these APIs, samples to get started, free map layers, and a gallery of live user sites to view applications built by others.

Virtual Globe Viewer—Download the latest version of ArcGIS Explorer, ESRI's free virtual globe viewer, from this site. ArcGIS Explorer can view data in 2D and 3D and incorporate user data and data available free from ESRI. Access free map layers, such as topographic maps, shaded relief, and world transportation, from this page.

Mapping for Everyone also includes a Community section where you can ask questions and collaborate with others.

The Missing Component

Adding place when evaluating health risks

The value of GIS in enhancing response to emergencies, such as wildfires or hurricanes, is widely recognized. However, this technology can also play a lifesaving role in responding to catastrophes on a more personal level.

At TEDMED 2009, the Technology, Entertainment, and Design in Medicine conference, ESRI global marketing manager for health and human services Bill Davenhall recounted how this was brought home to him by a heart attack in 2001 that hit him so forcefully and unexpectedly that he referred to it as "a train wreck."

In his presentation Can Geographic Information Keep You Healthy? Davenhall suggested that a patient's geographic (or place) history should routinely be considered by physicians when diagnosing and treating patients.

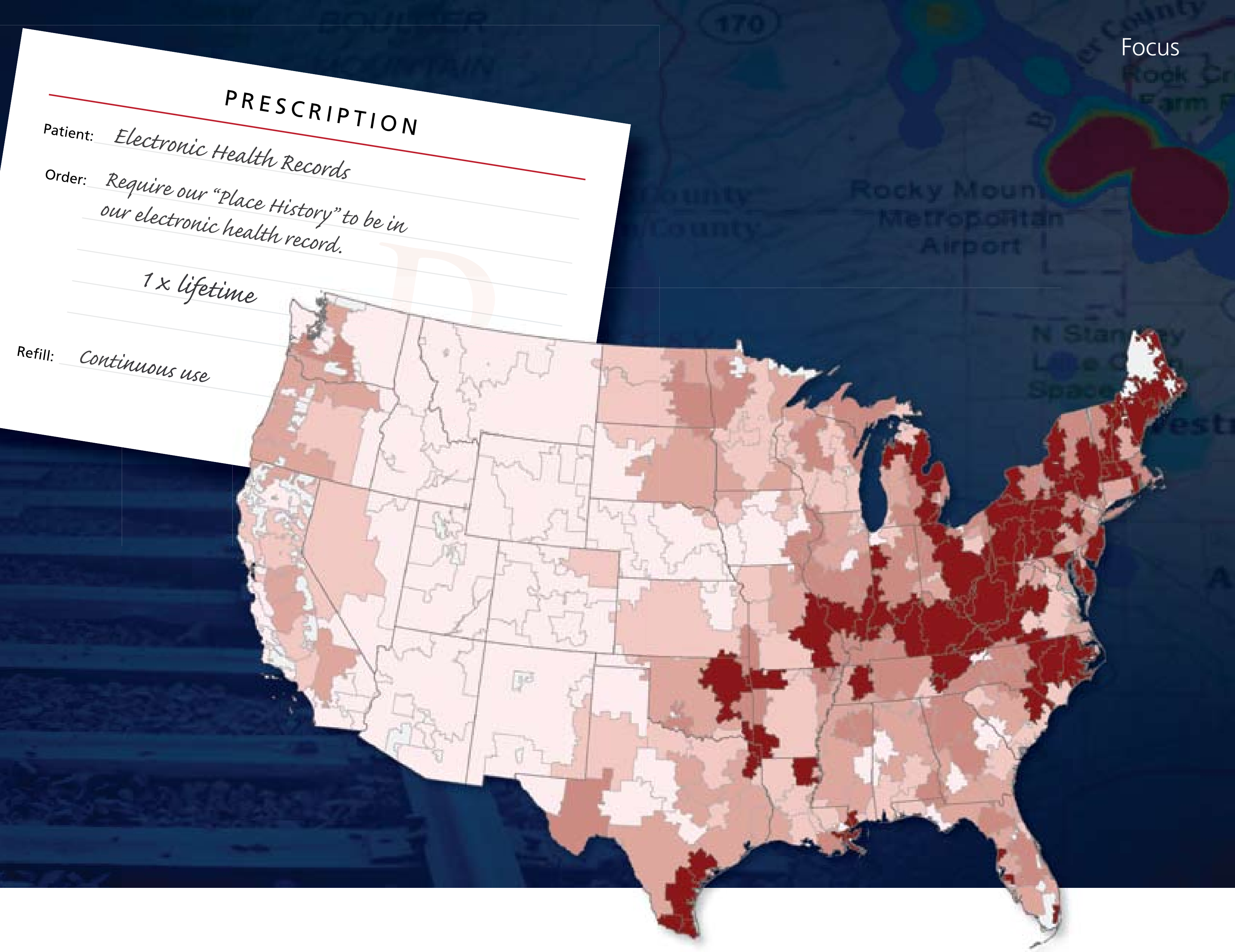
There is abundant evidence that the use of GIS has dramatically impacted the public health. Medical epidemiologists have extensively used GIS to establish the relationships between person, place, and time as these factors pertain to disease outbreaks. GIS has also been used by public health officials to protect communities from otherwise overlooked risks and toxic exposures. However, the geographic component has been remarkably absent from the treatment of individual patients.

For individuals, health risk factors can be expressed by a simple formula: Genetics + Lifestyle + Environment = Risks. Patient histories focus on the first two factors but completely ignore the last. When taking a patient's medical history, questions deal with the health and medical conditions of a patient's relatives (genetics) and the patient's personal habits (lifestyle) but nothing is asked about where the patient lives or has lived.

Davenhall observed that a great deal of research has been invested in relating what happens in the environment to human health but "this information is not used in a direct way by your doctor." Geospatial technologies have the potential to help diagnose, treat, and, in some cases, prevent illness. The emerging field of geospatial medicine, or geomedicine, could generate a type of medical intelligence that leverages national spatial data infrastructures to the benefit of personal human health.

The key to delivering geospatial intelligence to health care professionals requires capturing and accessing information about where a patient lives and has lived—that patient's place history. The widespread use of geospatial technologies is making capturing this information increasingly easy. The ubiquity of the Internet makes accessing this information from virtually anywhere equally simple.

During his presentation, Davenhall demonstrated a simple application developed for the iPhone for collecting a personal place history.



This information could be shared with medical personnel when necessary. This patient itinerary could be used to unlock everything known about the places that person has lived in or visited—the air, water, ground, food, culture, demographic characteristics, and other factors that can affect well-being.

According to Davenhall, where a person lives and works "has everything to do with the quality of your health." He used his own life's journey to illustrate this assertion.

For the first 18 years, Davenhall lived in Scranton, Pennsylvania, a place that has been designated by the Environmental Protection Agency seven times in the past 20 years as the most polluted environment in terms of sulfur dioxide, carbon dioxide, and methane gas emissions. His home for the next 25 years was Louisville, Kentucky, an area known for the production of polyvinyl chloride products, such as PVC pipe, and all kinds of plastics that require chloroprene and benzene for their production. These substances cause conditions such as leukemia, brain cancers, and central nervous system disorders. California, Davenhall's most recent home, suffers from pollution caused by particulate matter, carbon dioxide, and ozone.

After considering his place history, Davenhall realized that he had—quite unintentionally—managed to live in some of the most polluted areas in the United States. When he looked at maps produced by the National Institutes of Health showing areas in the United States where people are most likely to have heart attacks, he discovered that if he had wanted to have a heart attack, he had lived in exactly the right places. These places, symbolized in red, were where inhabitants are exposed to conditions or environmental triggers that can cause a heart attack.

However, all this relevant and vital information was missing from his medical record. Not only was there no place for place history in his record but his physicians wouldn't have known how to use it if it had existed. Currently, medical students typically aren't exposed to a curriculum that would help them make these kinds of connections.

As Davenhall noted, place history doesn't supply cause and effect because, "For most of the problems we have as humans walking around this planet, there will never be a strong cause and effect. But there will be a lot of correlation and a lot of association."

He offered two prescriptions to improve this situation. First, physicians need to understand the importance of geomedicine and that will be accomplished through funding geomedical curriculum in schools. Loma Linda University in Southern California has been a pioneer in this area and recently opened the Health Geoinformatics Laboratory center. *(See the accompanying article, "Designing Healthy Communities: Health Geoinformatics Laboratory opens," on page 13.)* His second prescription is to make a space for history in the electronic health records systems that are being developed.

"So I always now say geography does matter. It matters to me. I know it personally," noted Davenhall. "And I would hope that all of you could see that GIS is a technology and information that can keep you healthy."

Helping Shape Global Health

By Bill Davenhall, ESRI Global Marketing Manager, Health and Human Services

The use of GIS is rapidly spreading across the world as one of the most important technologies that helps nations address their most serious health goals including reducing disparity in the medical services available, improving access to services, and preventing the spread of disease. Striving for ubiquitous health could mean health everywhere, anytime. I acknowledge that health is on a continuum—one does not arrive at good health accidentally. Personal health begins before birth and continues throughout a person's life. Access to health and human services has become one of the major determinants of the degree of health attained. Multiply one person's health by billions, and this brings us to global health.

The strength of modern GIS technology extends well beyond geographically relevant data analysis and powerful data visualization. It excels as a medium that helps inform, organize, and deliver health and human services. GIS supports every Web-based service locator, every directions-finding Web site, and every consumer-facing information and referral service sponsored by health organizations.

As nations strive to protect their citizens from the threat of infectious diseases, such as legionella, dengue fever, West Nile virus, tuberculosis, or avian influenza, GIS has become an important technology for adding intelligence to existing disease surveillance systems at the local, regional, and national levels. GIS technology's ability to author, publish, and share critical information about the spatial dynamics of disease makes it, without exception, the technology of choice for accelerating the detection and identification of disease clusters. GIS technology's capacity to reach beyond geopolitical boundaries makes it highly desirable in public health emergencies and responses.

As every person is different, so is every community and nation. However, the varied ways that information technology is used seem fundamentally parallel. The way GIS is used by health and human service organizations and the professionals who lead these organizations is more similar than dissimilar; therefore, one of the greatest promises of GIS is its ability to speak a common language. In my opinion, developing a common language about health and human services helps nations move forward.

The adoption of any information technology is ultimately a function of its ability to produce results such as creating evidence, identifying inequities, better informing decision makers, and aiding more responsive actions and interventions to protect human health.

Today, more than 90 national health ministries located across every continent license some type of ESRI technology, from ArcGIS Desktop to the enterprise enabler ArcGIS Server. In developing nations where modern information technology is resource challenged, ESRI software is being deployed in the form of specialty epidemiological software distributed at low or no cost to health professionals through organizations such as the World Health Organization, Pan-American Health Organization, and the U.S. Centers for Disease Control and Prevention.

As GIS technology continues to enjoy wider adoption in health and human service organizations across all types of government and private health care organizations, knowledge about our communities—especially how our local environments impact our personal health—will command greater attention by community leaders everywhere. The ability to respond to emergencies and prepare citizens for disasters such as pandemics cannot be overlooked or under-resourced in regard to information systems.

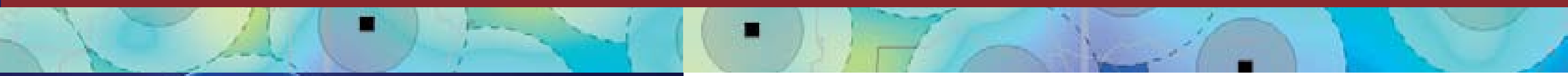
Global health begins at home. The obligation of nations to help citizens have a safe, healthy passage through life is neither a small nor simple matter. Dedication by health professionals in building effective systems and practices must be supported by evidence and results. It also takes knowledgeable people and progressive technologies to promote confidence in the information that is communicated.

In my opinion, delivering on the goal of global health requires unrelenting devotion to leveraging today's knowledge and technologies to mitigate the problems we face today. GIS will certainly play a large role in moving communities and their nations forward, and when we move forward, everyone everywhere has a better chance to attain the optimal health that is so needed in the world.

Designing Healthy Communities

Health Geoinformatics Laboratory opens

International Symposium on Healthy Communities
ESRI and LLU will jointly host the first Designing the Healthy Community international invitational symposium. The meetings are intended to bring together the best minds in public health to share new ideas about using GIS to make the world a healthier place. The inaugural event is planned for 2010 and will be held at both the Loma Linda University campus and ESRI's Redlands headquarters.



A new center at a Southern California university will help students learn how to use GIS to better understand and improve human health across the world.

The Health Geoinformatics Laboratory center at Loma Linda University (LLU) in Loma Linda was recently completed at a cost of approximately $85 million. The lab is equipped with GIS software including ESRI's spatial statistical tools for public health epidemiology, specialized logistical software for optimizing health care delivery, and geographic digital dashboards that enhance health informatics. It will provide undergraduate and graduate students with hands-on experience in applying modern information system technologies that combine maps and satellite imagery with data about the geographic locations of diseases, health care resources, and sociodemographic characteristics of communities.

LLU has been a pioneer in the field of health geoinformatics. Geoinformatics employs specific tools and techniques for acquiring, analyzing, and presenting geospatial data. Health geoinformatics applies these tools to data about location, demographics, and the environment to improve public health.

In 1996, the school's faculty designed and taught the first graduate-level GIS course offered at a school of public health in the United States. Two years later, LLU also became the first U.S. university to offer a bachelor's degree in health geographics. A graduate-level certificate in health geoinformatics, designed to complement existing degrees or provided as professional continuing education, was offered beginning in 2004. Three GIS tracts—Global Health and Development, Business Administration, and Environmental Health—have since been added.

LLU, a Seventh-Day Adventist health-sciences education institution, has eight schools with more than 55 programs and more than 4,000 students. Currently, undergraduate students at LLU can pursue a bachelor of science degree in public health, health geographics, and biomedical data management, and graduate students can obtain certificates in health geoinformatics and specialized offerings in areas such as environmental health, global health and development, and spatial epidemiology.

The lab is a critical part of the university's objective to connect with the world and think about problems in a different way. ESRI president Jack Dangermond observed that the new lab will combine great talent in health science education with emerging talent in technology in the geospatial field. "We are moving from the position of using geographic information systems to describe the world to help us take responsibility for the future of our world. This center will participate in that evolution of designing our future and participating in building a healthier world."

Targeting
Local Library Patrons

Photo courtesy of Michael Perkins, TSCPL

Although the Topeka and Shawnee County Public Library (TSCPL) serves a population of 173,000 that is spread over more than 500 square miles, it has only one building located in Topeka, Kansas. TSCPL deploys services using four bookmobiles and many outreach programs including mailing any library item.

Tapestry weaves common characteristics into community profiles

By Jim Baumann, ESRI Writer

A Kansas library district used Tapestry, an ESRI data product, and analysis provided by a GIS consulting firm to learn more about its patrons so it can better identify their needs, develop and manage services delivery, and market its services effectively.

Market segmentation is well known in the business community, which has used it successfully for many years for ongoing activities such as business expansion, site selection, competitive analysis, marketing campaigns, and many other common business procedures. However, it is gaining increasing use among public entities, such as libraries that need a greater understanding of users so that they can better serve them. Tapestry Segmentation classifies U.S. neighborhoods into 65 distinctive segments based on their socioeconomic and demographic composition. The analysis also provides lifestyle information including interests and buying habits.

When recently faced with preparing a strategic plan called The Next Decade, Gina Millsap, executive director of the Topeka and Shawnee County Public Library (TSCPL) in Topeka, Kansas, decided to conduct an analysis of her community and its library patrons. “We contracted with CIVICTechnologies to work with us by utilizing GIS data analysis to correlate customer, circulation, materials, and programming attendance statistics with demographic and marketing segmentation data,” said Millsap. “It was our hope that this approach, in contrast to the traditional user and community surveys, would tell us much more about who is using the library, how they are using it, what they aren’t using, what they might be interested in using, and who isn’t using library services.”

ESRI business partner CIVICTechnologies develops GIS-based solutions for public agencies and nonprofit organizations. In this case, the goal of the analysis was to identify underserved segments, assess their needs, develop appropriate resources to meet those needs and deliver those services, and implement a marketing campaign targeted at selected segments. This analytic process began with mapping the relationships between patrons and nonpatrons and examining checkouts, material types, and market segments.

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Targeting Local Library Patrons

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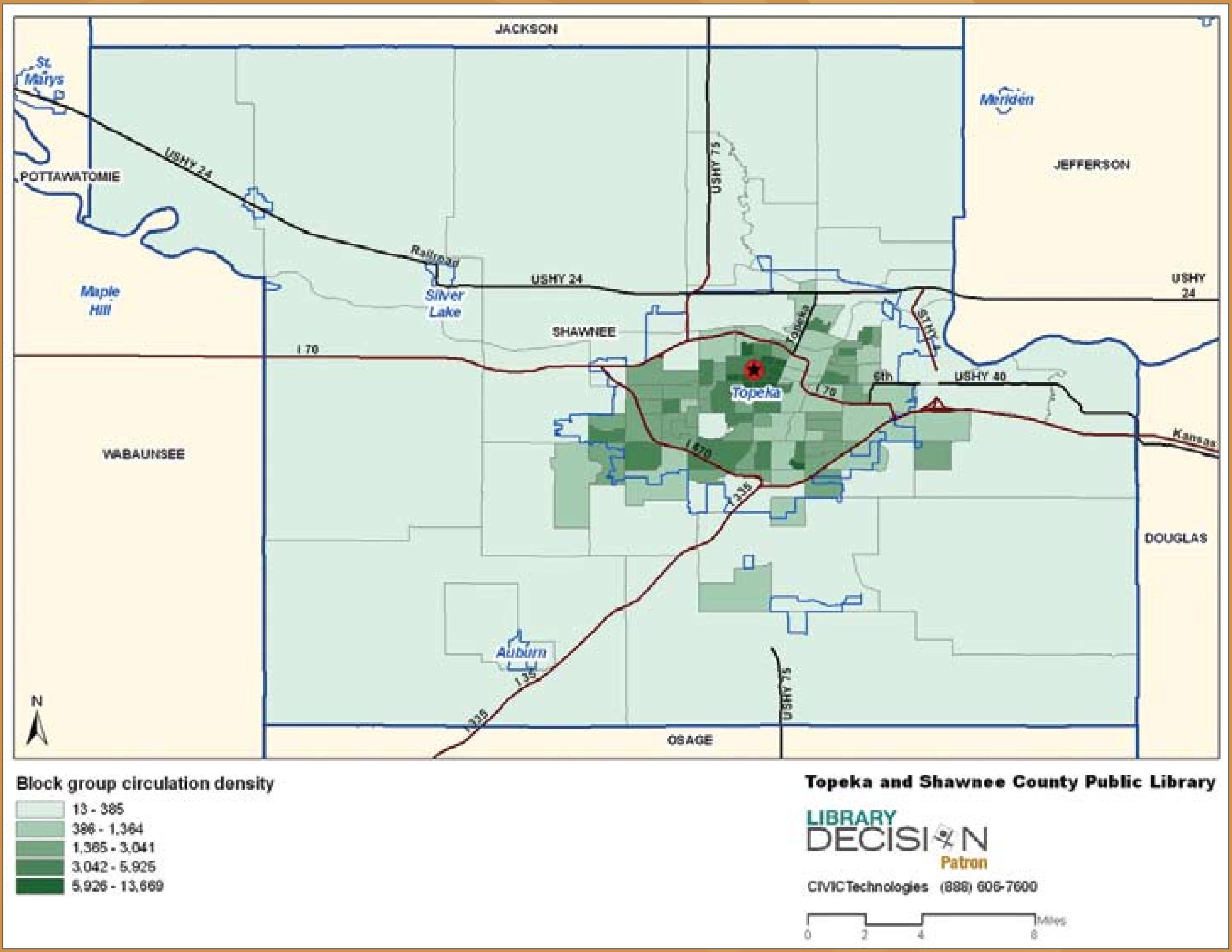


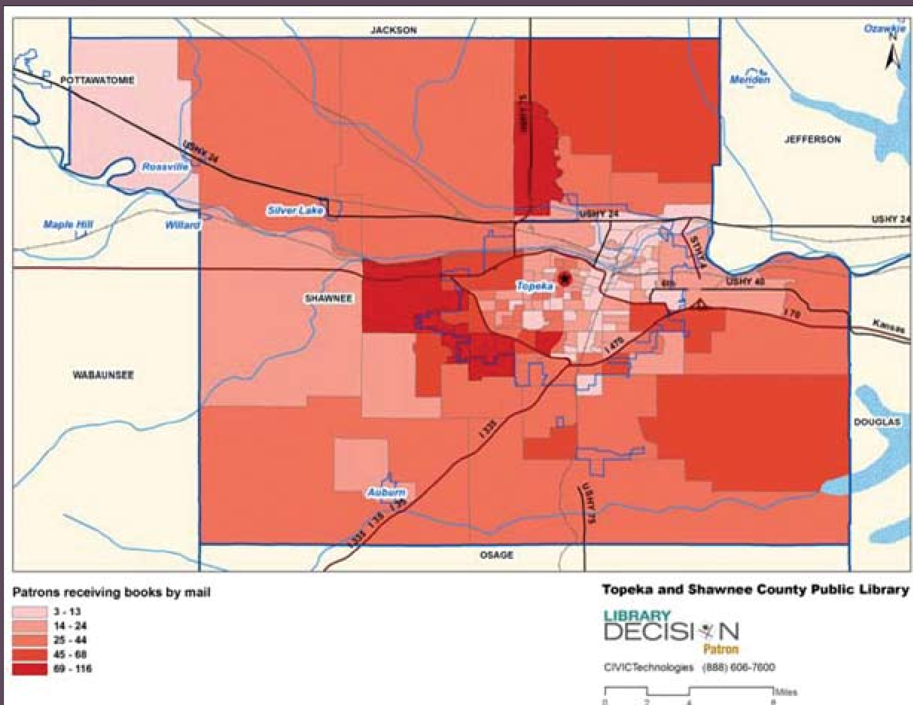
GIS analysis told the library more about its patrons than traditional survey methods.
Perception: ***People who live in eastern Topeka are generally underserved and are not big library users.***
Reality: ***Seventy-seven percent of inner city tenants are library customers and are the fifth highest segment in terms of items checked out.***

CIVICTechnologies uses Tapestry Segmentation in developing community profiles. Six primary Tapestry market segments—Green Acres, Rustbelt Traditions, Home Town, Exurbanites, Midlife Junction, and Cozy and Comfortable—accounted for 53 percent of the population served by the library, with the remaining 47 percent fragmented across 24 other segments. Each segment was ranked for its potential to add patrons and increase library checkouts. This information helped TSCPL identify needs, as well as develop and manage its service delivery and marketing programs.

Marc Futterman, president and CEO of CIVICTechnologies, noted, "In contrast to TSCPL's top six segments, inner city tenants (a segment typically considered underprivileged) accounts for only 1.1 percent of the population, or 1,916 people. For TSCPL, this segment represents the highest patron penetration rate among all 30 segments—77 percent of inner city tenants are patrons—and the fifth highest average checkouts per patron (1.78 items). In this case, the library is providing exceptional service to a market that is often considered underserved.

"Service to juveniles and young adults is also very important to the TSCPL program. We ranked the potential to increase youth patronage and checkouts in each of the 30 segments. The Home Town segment, for example, has a good potential for increasing youth patronage and checkouts, as evidenced by its dominant share of youth checkouts. The behavior of youth in census block groups with high checkouts can serve as a model for increasing checkouts in the census block groups with the lowest checkouts."

Another important result of the analysis came from comparing print and nonprint materials by segment. Nonprint materials were



The analysis provided insights into how patrons were using the library's services.
Perception: ***Customers living the farthest from the library use the mailing service the most.***
Reality: ***Distance from the library is not a good predictor of how much customers use the mailing service.***

"My own epiphany about planning after working for more than 30 years as a professional librarian is that the line between a library's strategic plan and its marketing/communications plan has begun to blur and merge. It is really all about connecting with people and building relationships built on real knowledge about each other. And the data that drives that is the GIS analysis."

highly favored by segments whose characteristics include close proximity to the library; modest incomes; and a diverse range of household types, ages, and life stages. TSCPL is currently developing targeted marketing programs to increase use of both print and non-print materials in these segments and identify other segments with similar characteristics that are likely to use these resources.

The analysis has provided the library with a great deal of information about their current and potential users within the determined market segments. For example, those living farthest from the library are located in Shawnee County and are members of the area's largest population segment called Green Acres, which is spread throughout the rural parts of the county. Segment characteristics indicate that it is family oriented, well educated, middle class, and not ethnically diverse. It is also one of the most underserved library segments within the TSCPL. There are 23,999 people in this segment and 9,409 of them have a library account, which means that 61 percent of this group are not current library users. The segment represents 13.7 percent of the total population of the Topeka and Shawnee County area and 10.7 percent of the area's library customers. In addition, for those in this area that use library services, these patrons check out 1.32 items every couple of months. The TSCPL analysis has shown that to meet the needs of the overall community, service must be improved for this particular segment. TSCPL is currently considering various options, such as increased bookmobile visits, books-by-mail services, services through local schools, or opening local storefront facilities.

After completing the analysis, the library was able to identify trends, patterns of usage, service, collection, and programming preferences, as well as barriers to using the library, most of which they were previously unaware of. Concluded Millsap, "Tapestry data has been especially helpful in getting to know our customers by looking at their lifestyle choices, consumer buying habits, and so on, as well as basic demographic information and comparing that to how they use (or don't use) the library. We now have a very clear picture of our open market potential, and we're beginning to understand the strategies we need to pursue to increase satisfaction of existing customers, increase usage of existing customers, and grow our customer base from 94,000 account holders to approach the 173,000 people that live in our service area.

"My own epiphany about planning after working for more than 30 years as a professional librarian is that the line between a library's strategic plan and its marketing/communications plan has begun to blur and merge. It is really all about connecting with people and building relationships built on real knowledge about each other. And the data that drives that is the GIS analysis."

Portions of this article appeared previously in the October 15, 2008, issue of Library Journal *and are printed here with its permission.*

Mapping Riparian Vegetation with Lidar Data

Predicting plant community distribution using height above river and flood height

By Thomas E. Dilts, Jian Yang, and Peter J. Weisberg,
University of Nevada, Reno

Combining GIS and lidar data enabled predictive mapping for riparian areas for a portion of the Sierra Nevada mountain range.

Riparian areas pose many problems for vegetation modeling because of their narrow width, dendritic pattern, and the sensitivity of plant species to subtle changes in topography that cannot be easily recorded by coarse-scale digital elevation models (DEMs). Vegetation mapping and monitoring in riparian areas have relied heavily on field-based surveys that record the distribution of plant communities along transects perpendicular to the river.

Typically, these studies also collect ancillary variables, such as stage elevation or height above the river (HAR), soil texture, and soil moisture, that are used to predict the distribution of vegetation types. However, these methods are extremely time consuming and do not allow for the development of predictive maps because the data collected cannot easily be extrapolated to a larger region. GIS and lidar data provide an opportunity to derive variables, such as HAR, for large areas, making wall-to-wall predictive mapping a possibility.

Deriving HAR from Lidar Data

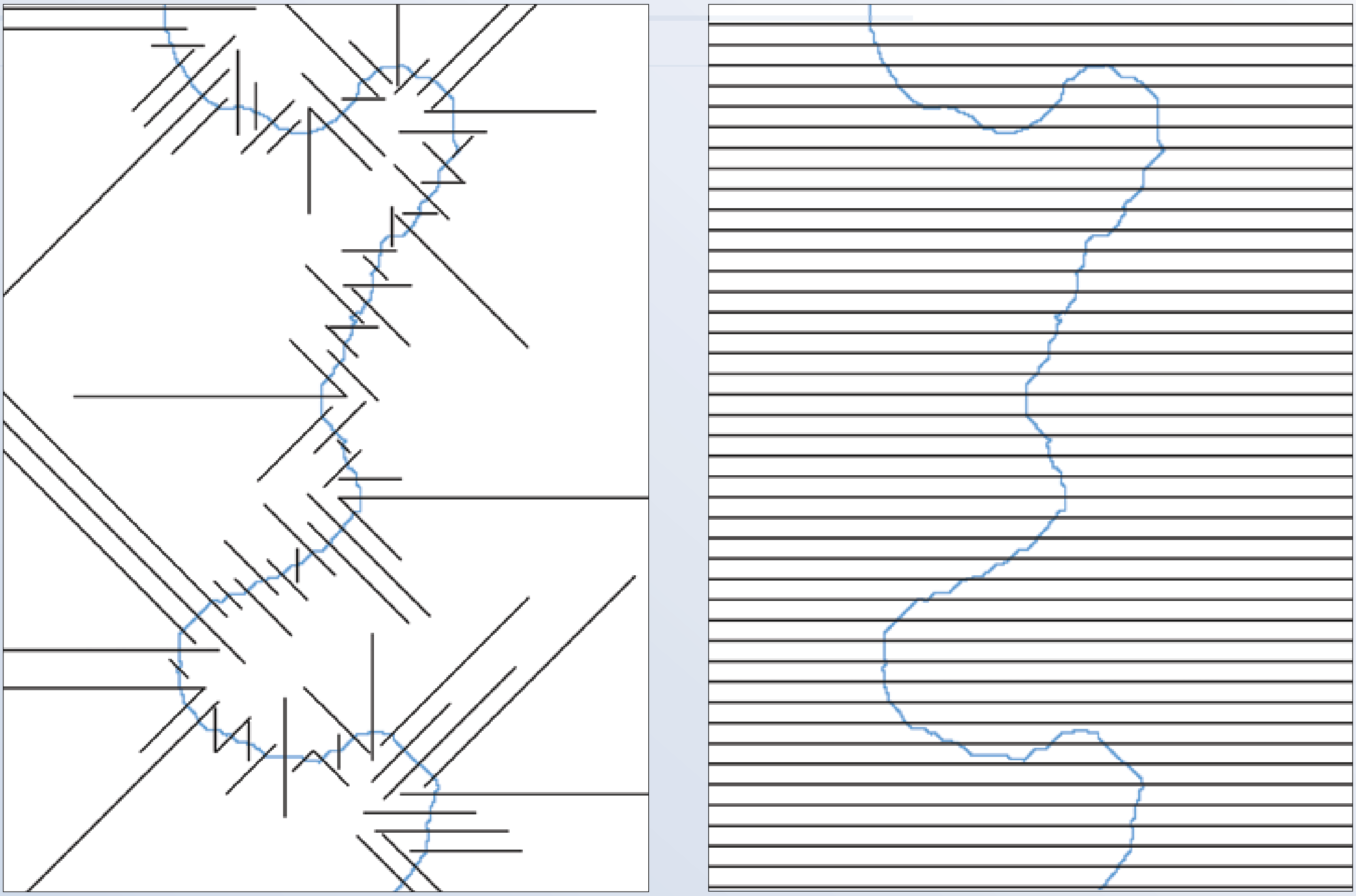
Developing cross section profiles akin to traditional survey methods posed a number of problems. It is time consuming to digitize the thousands of cross sections that would be required to cover the entire 200-mile stretch of the Walker River, which runs from the Sierra Nevada range in eastern California to Walker Lake in western Nevada.

However, automated approaches for generating transects also entail problems. If the transects are generated perpendicular to the river, the density of transects is less on the outside of a river bend than on the inside of that river bend. If transects are generated perpendicular to one another, they do not always cross the river at right angles. One-dimensional methods also suffer from problems because points located on different transects may be close to one another geographically yet have very different values because the transects they are on intersect the river at different elevations. When producing a predictive map from such data, the result is many abrupt changes over small areas that make the map difficult to interpret.

The authors of this study considered two-dimensional methods as an alternative to the traditional one-dimensional method of constructing stage elevation from lidar data. Hydrologic functions in the ArcGIS Spatial Analyst extension were used to fill the DEM (i.e., to remove local "sinks" caused by errors in DEM construction) and calculate flow direction and flow accumulation for each grid cell.

The resulting flow accumulation grid was reclassified and subsequently edited so that the resulting stream network only included cells where the Walker River was located. A custom model was developed using ArcGIS ModelBuilder to calculate HAR. The model uses the Spatial Analyst extension's kernel density function to calculate a distance-weighted average of river elevations, where cells in the river that were nearer to the upland grid cells receive a greater weight than cells located farther away. The weighted average river elevation was then subtracted from the elevation of individual grid cells to derive HAR for each location.

ModelBuilder, part of ArcGIS Desktop, was also used to derive additional variables from the HAR grid. Spatial Analyst cost-distance functions were used to identify grid cells below a user-specified HAR threshold that were physically connected to the river channel. This algorithm was extended iteratively using ModelBuilder to calculate inundation areas at one-centimeter vertical intervals up to five meters above the river. The inundation values from each iteration were summed and subtracted from 500 to get a flood height grid. The flood height grid describes the flow stage required to inundate a given grid cell, assuming a simple bathtub model. *[A bathtub model is a steady-state water quality model for simplifying the assessment and prediction of conditions in reservoirs and lakes as related to eutrophication.]* Low-lying cells separated from the river by higher ground required a flood height greater than the HAR value.



The figure on the left shows cross sections that have been generated perpendicular to the river crossing the river channel every 10 meters. The figure on the right shows horizontal cross sections that are generated every 10 meters. Both figures illustrate the problems with automated methods of generating cross sections. On the left, large gaps are left in areas where coverage of cross sections is poor. Where cross sections come close to one another, values can differ greatly because they refer to different parts of the river. On the right, the cross sections can intersect the river in more than one location.

Results

The HAR method described here produced maps that were smoother, easier to interpret, and required less time to produce than ones created using comparable one-dimensional methods. All calculations were performed using ArcGIS and the Spatial Analyst extension and did not require fieldwork. The kernel size can be adjusted to vary the extent and smoothness of the height-above-river map. Larger kernel sizes incorporate longer stretches of the river into the calculation allowing greater mapping extent and a smoother surface. A smaller kernel size results in a smaller extent but more detailed and more precise estimates.

Estimates appear to be most accurate along low-gradient stretches of the river with few tributaries. These are precisely the same areas where a typical low-resolution DEM would have the most difficulty detecting subtle changes in elevation. Stretches of river with a nonlinear gradient and tributaries with strongly differing gradients are likely to produce less accurate results.

HAR and flood height were incorporated into statistical models to predict the distribution of vegetation communities within the Walker River Basin. When predicting the 10 major vegetation communities in the basin, HAR and flood height were the first and second most important predictor variables. Wetland vegetation and communities dependent on frequent flooding exhibited the lowest HAR values, while communities that tended to be located farther from the river but were still dependent on groundwater exhibited higher HAR values. Upland communities able to tolerate low water tables had the highest HAR values.

Future Directions

As restoration efforts move forward for the Walker River Basin, HAR and flood height maps will be incorporated into a decision support system that helps land managers identify low-lying areas that can be reconnected to the river channel. Using HAR and flood height maps

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Mapping Riparian Vegetation with Lidar Data

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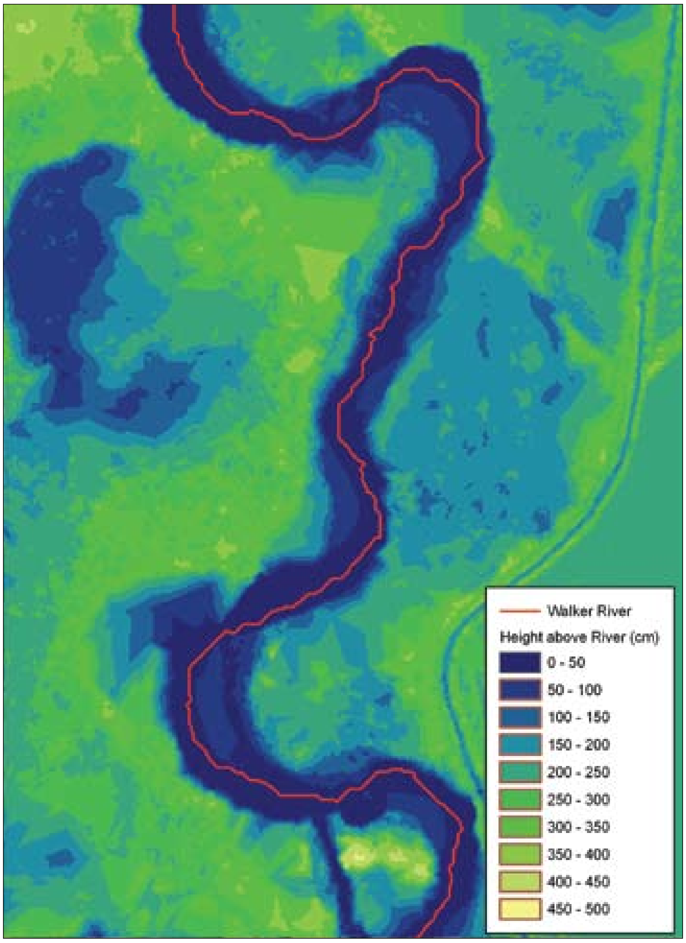

The figure on the left is a 0.3048-meter-resolution aerial photograph of the Walker River in Nevada. The image on the right is the height-above-river map using a 300-meter kernel size and classified into 50-centimeter vertical intervals. In the upper left-hand corner is a eutrophic oxbow lake that is low lying yet disconnected from the river channel. Near the bottom of the map is a shallow river channel that periodically fills with water, cutting off the point bar. An irrigation ditch is visible on the right-hand side of the image.

will help minimize costs by targeting areas where restoration is most likely to be successful. Currently the Great Basin Landscape Ecology Lab is using Toolbox for Lidar Data Filtering and Forest Studies (Tiffs) software developed by Qi Chen to delineate individual tree crowns derived from lidar. The individual tree maps will be used to map bird habitat and improve on existing vegetation maps for the Walker River Basin. Finally, the authors plan to make the HAR and flood height models available to the GIS community as part of the Riparian Topography Toolbox, which will be available on the ArcScripts Web site (www.esri.com/arcscripts).

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Acknowledgments

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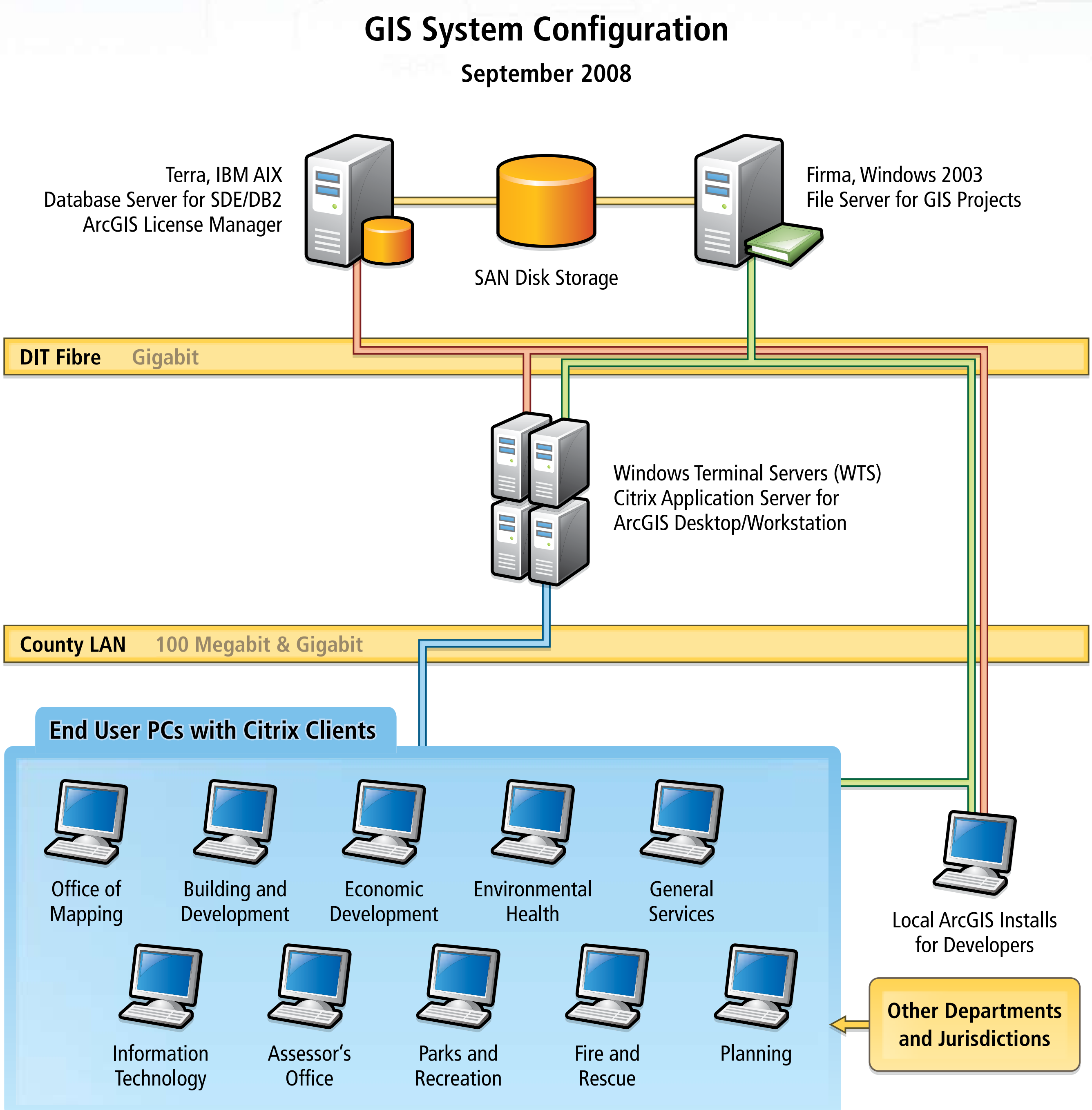
Application Aids Land Assessment Analysis

Replaces time-consuming paper process

By Julie Kottamala, Jennifer Sanderson, and David Torraca, Loudoun County, Virginia



Loudoun County GIS system diagram

Loudoun County, Virginia, has a mature enterprise GIS implementation. The county recently developed an application that integrates computer-assisted mass appraisal (CAMA) with GIS to improve the workflow of the county Assessor's Office. With this application, county appraisers can easily search, map, and analyze assessment data.

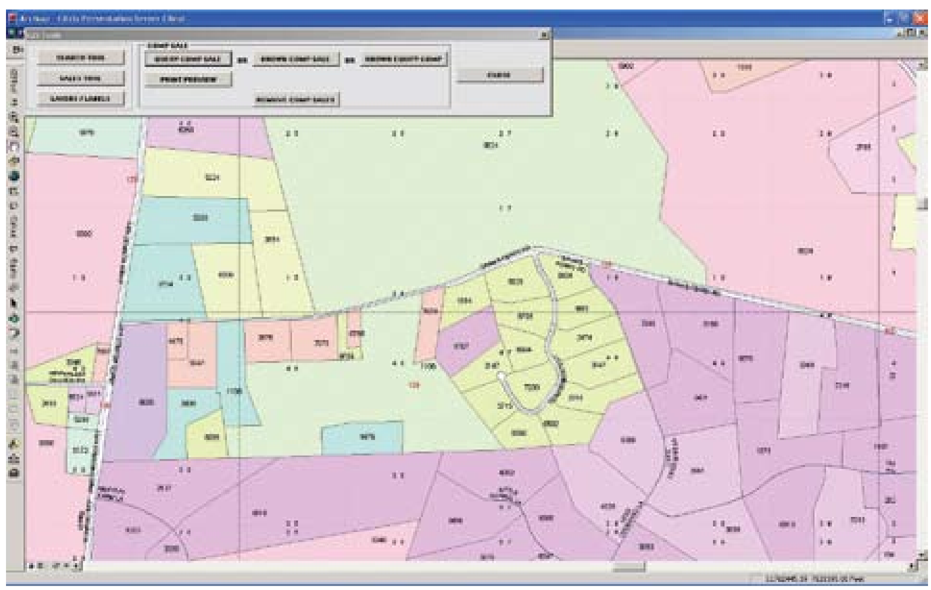
Loudoun County, Virginia, part of the Washington, D.C., metropolitan region, has experienced rapid growth since the mid-1990s. In 2008, the county had an estimated 98,000 households. Real property assessments have declined approximately 9 percent in the last two years, mirroring national trends in real estate values.

The county was an early adopter of GIS and has used ESRI products since 1986, developing processes to map property boundaries and assign addresses. Its GIS currently has more than 150 data layers and supports a wide range of internal users through ArcGIS Desktop products and intranet applications as well as hosting an Internet mapping site. ArcGIS Desktop is served through Citrix application servers while the database is managed using ArcSDE running on an IBM AIX server with DB2 as the underlying relational database. Since DB2 is the county mainframe standard, spatial data can be used in a variety of ways in conjunction with other county databases and systems including computer-aided dispatch (CAD) and permitting.

Past GIS Use: A Laborious Manual Process

The CAMA system used in Loudoun County is a mainframe system designed in the 1980s. It lacks functionality and requires a great deal of knowledge and expertise to manipulate the data from the CAMA system and link it to the GIS parcel layer. The Assessor's Office does not have dedicated mapping staff, so staff appraisers must work with the GIS staff to map any detailed assessment data. Appraisers download assessment data to spreadsheets that are given to the GIS staff. These spreadsheets are joined to tables in the county's GIS so assessment data can be mapped. This time-consuming process was required even when an appraiser simply needed to review data and didn't need a printed map.

Alternatively, appraisers could view data using WebLogis (www.loudoun.gov), the public mapping program created by the GIS staff using ArcIMS to view GIS data. Appraisers must view their data in a separate window and the program does not include data needed by the appraisers, such as values, structure type, sales, improvement square footage, and year built. Appraisers must first use the parcel identification number (PIN) search to locate the parcel. Once the parcel is found, clicking the See Assessment button shows parcel ownership, structure information, recent sales, and tax history information for that parcel from the Real Estate Tax, Assessment & Parcel Database. The process must be repeated to view information on each parcel and is extremely time consuming.



Loudoun County Assessor's GIS main tool screen

Present GIS Use

To remedy this situation, Loudoun County created an easy-to-use application for the Assessor's Office that allows appraisers to map and query assessment data. The first version of this application was completed in September 2008. Since that time, five additional versions have been released. Initially it was used for querying and mapping assessment data, but later versions can perform analyses on this data.

Loudoun County's spatial data includes land records data (e.g., parcels, addresses, and centerlines) maintained daily in the geodatabase. Assessor's data on residential and commercial properties is maintained regularly as tables in the CAMA system. An external DB2 database called Parcel Database System (PDBS) contains the weekly upload of CAMA data that is maintained by Loudoun County's Department of Information Technology for data distribution purposes.

After identifying the information needed for the mapping application, an extract of PDBS tables containing the required fields is maintained in the GIS ArcSDE database and updated weekly. DB2 stored procedures are also used to instantly access the external PDBS database for creating callouts in the application or returning pertinent data by clicking on a map location.

The application provides access to specific GIS data layers and labels those layers with associated data (i.e., PINs and street names). To make the map more readable, the parcels are symbolized by shading them using the assessor's neighborhood codes. Users can toggle between different classifications for other analyses. To

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Application Aids Land Assessment Analysis

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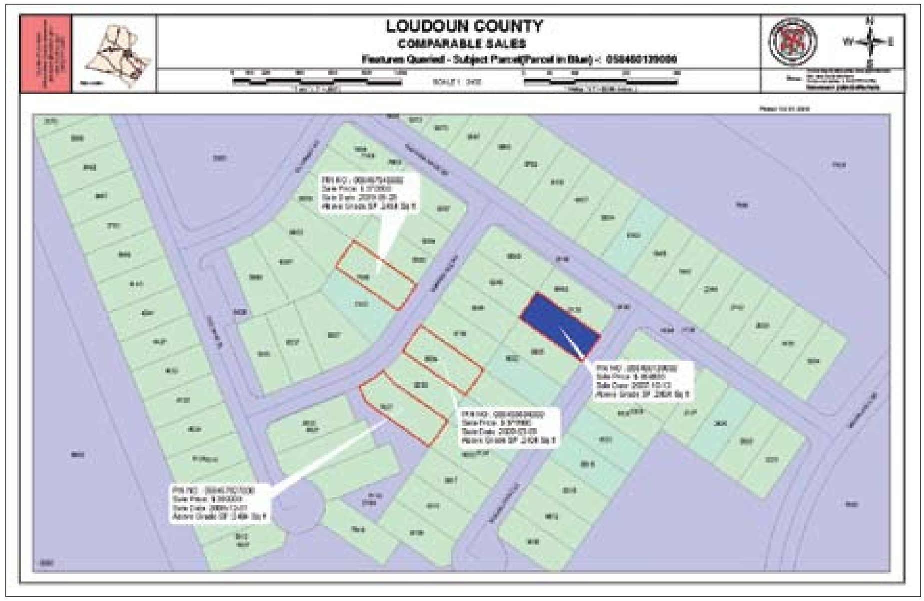
highlight the difference between residential and commercial parcels, the residential parcels are symbolized with hashes and commercial parcels with dots. The Layer/Labels tool allows an appraiser to turn on/off a few more layers such as Buildings, Golf Courses, Zoning, and Imagery. In addition to adding layers, this tool also allows users to pick and choose three more labels, from a list of 12, to add to the display.

The application has several tools for various functions such as identifying a parcel or a set of parcels. Clicking on a parcel lists all the assessor's data related to that parcel. Using the Polygon Parcels tool, an appraiser can draw a polygon on the map and generate a report with the assessor's data related to parcels within the selected area.

Speeding up map rendering was one of the goals for this application. Searching for parcels based on PIN, historical tax map number, neighborhood number, land neighborhood number, and subdivision is a common task, and the GIS database was relatively fast, but searching for data stored in PDBS using stored procedures and rendering the map was very slow. To improve this situation, the Search tool lets users search parcels either within the county or within a selected election district that provides many more search criteria, such as searching lot numbers, occupancy codes, sale price ranges, and improvement size ranges. The parcels returned in the search are highlighted and the extent zooms to the selected parcels.

Selected parcels can be further analyzed using the Sales tool. Often, an appraiser needs to search for parcels sold around a particular parcel or within a neighborhood or subdivision. The Sales tool allows an appraiser to identify these parcels that have sold within arranged selected dates and at a specified distance from the subject parcel. These properties are highlighted and listed in a report that can be exported to PDF or other formats.

Every April, taxpayers can appeal the assessed value of their properties. This process requires the Assessor's Office to provide three comparable sales to the Board of Equalization. This process is facilitated by the application's Comp Sale tool. This tool identifies the three most comparable sales for the appealed property. The appraiser can create a map showing the location of the subject parcel and comparable sales with callouts showing information such as sales price, sale date, and total price. These maps are used when the property is reviewed by the Loudoun County Board of Equalization.



Loudoun County Assessor's GIS Comparative Sales map

Future Enhancements

This application, although successfully implemented within the Assessor's Office, has limitations. To expand access to parcel information, a Web-enabled program is planned. In addition, appraisers would like to use the application to create routes to sites they must visit, access Multiple Listing Service (MLS) data, and view photographs of structures and adjacent streets. These enhancements should help the Assessor's Office continue working as efficiently and effectively as possible.

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David Torraca is the GIS manager in the Loudoun County Mapping & GIS Office. He has worked with Loudoun's GIS nearly since its inception in 1986 and has more than 20 years' experience in the mapping field. He holds a bachelor's degree in geography, a diploma in surveying and mapping, and a master's degree in public administration.

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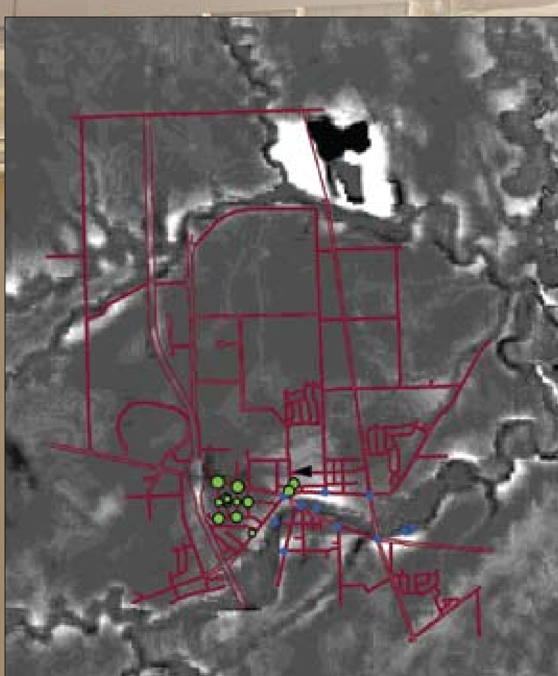
An aerial view of the flooding in the Village of Dundee. Flood levels reached the bridge leading into the downtown area, overflowing the local dam and numerous buildings.

Making More Informed Decisions

Helping small communities assess risk

By Craig A. Ries and David A. Kubiske, P.E., P.S. (Contributing Editor), David Arthur Consultants, Inc.



The digtal elevation model (here in gray scale) showing elevations in the Village's vicinity along with GPS data and GPS points marking some initial work on the CSO system shown as green dots

A small Michigan community was able to model potential flood levels and identify areas at risk by combining existing data with newly collected and highly accurate horizontal and vertical data around the floodplain.

For a community located near a sizable river, accurately predicting flooding and managing the associated risks can be a difficult and relatively expensive task. This is true for the Village of Dundee. Located in southeastern Lower Michigan, the village is bisected by a river. Like many communities in the 1970s, the village adopted a combined sewer outfall (CSO) system as a result of water quality federal regulations and statements from the Department of Environmental Quality (DEQ). CSO systems combine sewer and storm water systems to dilute outflowing sanitary effluent returning to a river.

Following changes in water pollution regulations and a better understanding of its causes, CSO systems were no longer endorsed. Under new regulations, CSO systems failed to meet the requirements of new laws. This was particularly true for the village due to overtaxing of the downriver treatment plant. Many communities replaced or modified sewer systems to meet the new regulations, and the village was no exception. It separated the storm and sewer lines it was aware of and

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An aerial view of the Village of Dundee with overlays of the rights-of-way (red lines) and a number of locations of GPS shot for elevation (blue dots), which indicate partial flood levels

Making More Informed Decisions

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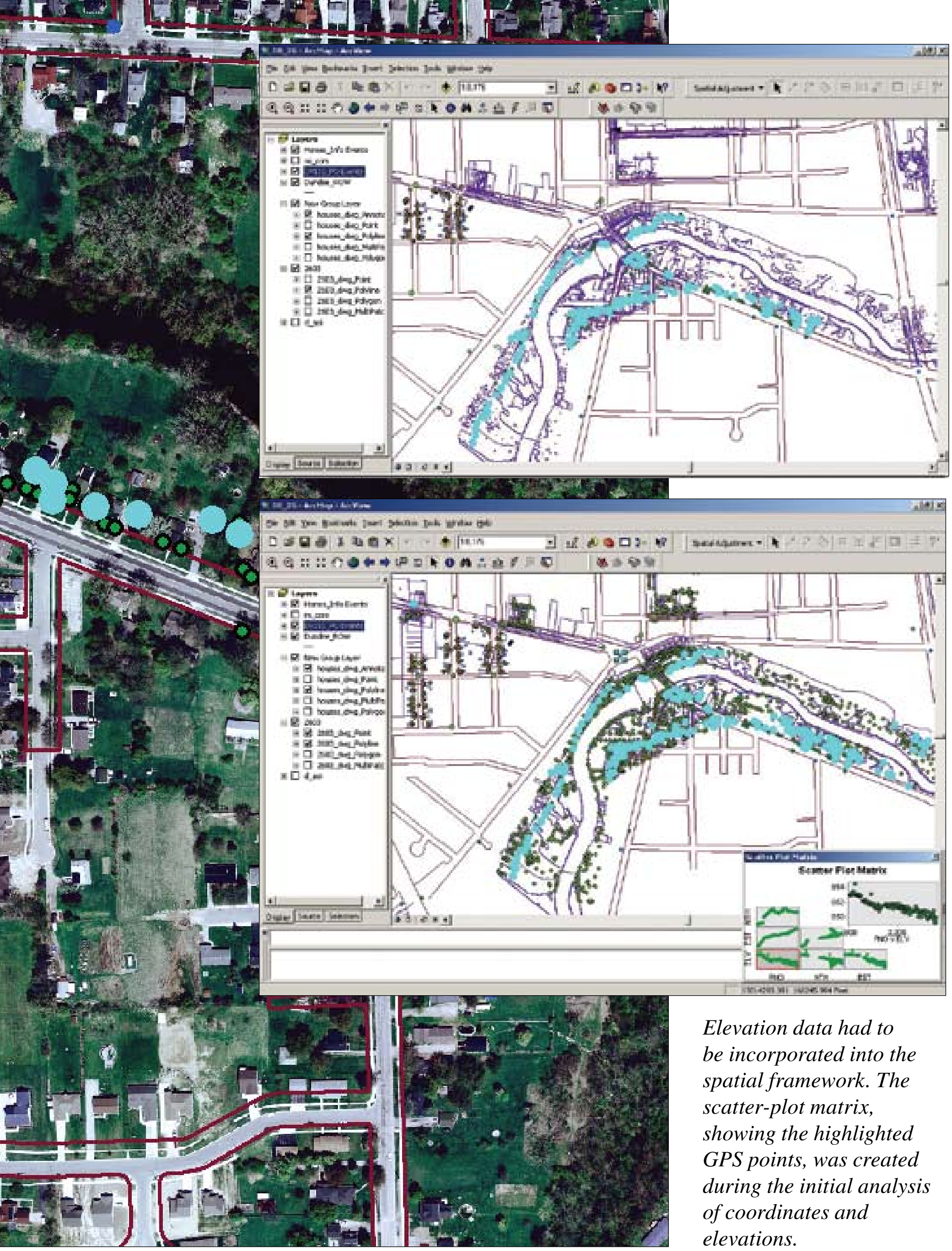
implemented better treatment measures to meet the newer requirements.

However, while the community was expanding, many older residential areas along the river had CSO-era and earlier systems that contributed excess rainwater to the river. This water went to the treatment plant, rather than the storm water system. Recently, the village made aesthetic improvements to the riverbanks—with DEQ approval—by adding a small number of structures along the banks that altered the river's flow, direction, and magnitude. These changes, both man-made and natural, modified the river and its flow enough that the floodplain map needed to be reevaluated. The amount and flow of water are the bases for calculating the floodway and floodplains.

In early 2008, an unexpected problem developed with the storm water system. Large amounts of rainfall diverted from homes to the river brought the problem to light. Older homes were diverting more water into the sewer system than had been anticipated. This caused the treatment plant to overflow into the river and eliminated its effectiveness as a water treatment plant. These homes returned excess rainwater directly to the sewer system via house foundation drains, roof downspouts, and sump pumps. Because periods of high rainfall could overflow the treatment plant, the village began fixing the remaining portions of the storm water system. However, there was no list to indicate which houses remained partially connected to the sanitary sewer system. The problem reoccurred in early 2009 when three days of rainfall caused the village to experience approximately a 100-year flood as defined by the most recently revised hydraulic analysis for river flow by the Federal Emergency Management Agency (FEMA).

The water reached levels recorded in the village only twice before by the National Oceanic and Atmospheric Administration (NOAA). This event raised a serious question: During a severe weather event, how can the village determine which residences and businesses are in the predicted floodplain so it can warn them?

To solve this problem and more easily



A selection of CAD layers provided groundwork for later GIS development.

Elevation data had to be incorporated into the spatial framework. The scatter-plot matrix, showing the highlighted GPS points, was created during the initial analysis of coordinates and elevations.

address unforeseen complications in the future, the village turned to GIS so many aspects of hydrology could be combined. With GIS, floodplains could be overlaid to help analyze and predict events rather than simply present data. The village already had most of the information needed to predict both flood levels and the specific areas that would likely be affected by any one flood.

However, while initially the data was available to decision makers, this data was separated into many files stored on many computer systems and could not be easily gathered or studied. The maps, AutoCAD files, miscellaneous spatial information, written memoranda, and other files needed to be combined with data collected from the area and presented in a way that would allow the village government to better analyze and address not just flooding problems but also other hydrology issues.

The existing information was sufficient to predict possible floods and their locations, but due to the problem with the storm water system, the extent could not always be predicted. The additional data on, for example, which houses needed to be removed from the sewer system, once collected and combined with the existing information, would not only allow the extent of possible floods to be better predicted but also assist in dealing with certain issues with the storm water system that was being modified.

It was determined that preexisting information would be merged in ArcMap. GPS data would provide more accurate elevations, digital images around the village would help better visualize and predict flood levels, and aerial and topographical maps would be overlaid to provide context for the entire village. The aerial and topographical maps allowed an additional analysis of the watershed for areas outside the floodplain to determine their possible effects on the village's storm and sewer water systems.

A field crew used GPS equipment to collect horizontal and vertical data around the floodplain. The project was concerned with a specific aspect of hydrology. Within this limited area, a more accurate topographical representation of the floodplain and the surrounding areas was required in part to correctly identify which homes and how much water shunted into the river and sewer system would be captured by the storm water system.

GPS was used to acquire highly precise horizontal and, even more importantly, vertical benchmarks so the many other kinds of information could be accurately incorporated. Of the information to be included, a correctly projected and transformed aerial raster set for the entire village was the most challenging to obtain. With this accomplished, the rest of the project could correlate this information with the topographical data relating to the river and the storm water systems throughout the village. Both systems play a large role in the dynamics of the watershed and risk of flooding.

With a basemap and the rest of the information for the entire village in place, proper analysis could be performed at a much higher level of specificity, and these analyses could be more easily performed for future hydrological projects.

Through careful spatial analysis using ArcGIS, small and rural local governments can make more informed decisions regarding their existing infrastructure. Many of these communities already have the necessary data at their disposal but lack an effective way to leverage this disparate data. GIS can give these governments a tool to better analyze their existing knowledge base. For more information, visit the ArcGIS Resource Center for Water Utilities at resources.esri.com/WaterUtilities.

About the Author

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GIS Gives Port a Common Operating Picture

New users and data reuse optimize port activities

By Karen Richardson, ESRI Writer

A server-based enterprise GIS implementation created by the San Diego Port Authority has empowered staff across the organization by centralizing the maintenance of and access to GIS data and CAD drawings.

"Our vision of creating a common operating picture with a geographic perspective gives everyone the information they require along with the basic GIS functionality necessary to do their jobs in the best way they can."

Malcolm Meikle, GIS Coordinator for the San Diego Port District

The Port of San Diego maintains a diverse facility spread across 6,000 acres. With the exception of the San Diego Convention Center, the San Diego Port Authority is responsible for the port: park and concessionaires, the walkway, large public art installations, the commercial shipyards and ports, and the recreational boating marinas surrounding San Diego Bay. Operating these assets generated revenues of $133.7 million in 2007. The port, which uses information technology (IT) enterprise systems, such as SAP and a document system to manage business information, realized that applying the same concept to space management would be advantageous. The system the port envisioned would be accessed by every department and used by anyone from summer interns to the CEO.

The port had been using GIS since the 1990s in the engineering and real estate departments. Although both departments were essentially creating and using the same data, this data was not shared and efforts were duplicated. However, there was no easy way to share data.

"Our vision of creating a common operating picture with a geographic perspective gives everyone the information they require along with the basic GIS functionality necessary to do their jobs in the best way they can," explained Malcolm Meikle, geographic information systems coordinator for the San Diego Unified Port District.

Making GIS Part of the Daily Workflow

Three years ago the port's information technology department added ArcGIS Server, a complete and integrated server-based GIS, to its ArcGIS Desktop software. This change made facilities data accessible to the departments that needed it. The goal was to streamline workflows by identifying tasks, questions, and requests that were best answered using a geographic approach. This approach paid off.

"Using GIS, the time it takes to access critical information went from seven to eight hours to mere minutes because the data is now located in one location and it is up-to-date," said Meikle. "Just this change has sped up our workflow and is driving faster, more informed decision making."

The port worked with various departments to customize interfaces using ArcGIS Desktop and generic Web browsers to give access to port data that now resides in a single location: a geodatabase. The geodatabase is the common data storage and management framework for ArcGIS Server. Source data is also managed in the geodatabase, which minimizes redundant copies and eliminates the possibility of varying versions of data.

Adopting new technology to improve business processes can be a daunting task. The port found it needed to keep daily tasks as unchanged as possible while incorporating tools for bringing real benefits to the users. CAD has continued as the technology used in the data production environment for creating drawing files for structures around the port. Designers use the ArcGIS for AutoCAD extension, a free tool from ESRI, to bring GIS data into the CAD environment. Using this extension, engineers can continue working with familiar software while gaining access to GIS data. It can be GIS data created in-house or GIS data from ArcGIS Online, an ESRI-hosted repository of GIS maps, layers, and tools.

ArcGIS for AutoCAD has proven to be a valuable tool since it allows operators to see the GIS basemap in their native CAD environment and find answers to questions because all the information is accessible through the basemap. "AutoCAD users are drawn to this tool because it gives them a window into GIS information while still allowing them to work in their familiar AutoCAD environment," said

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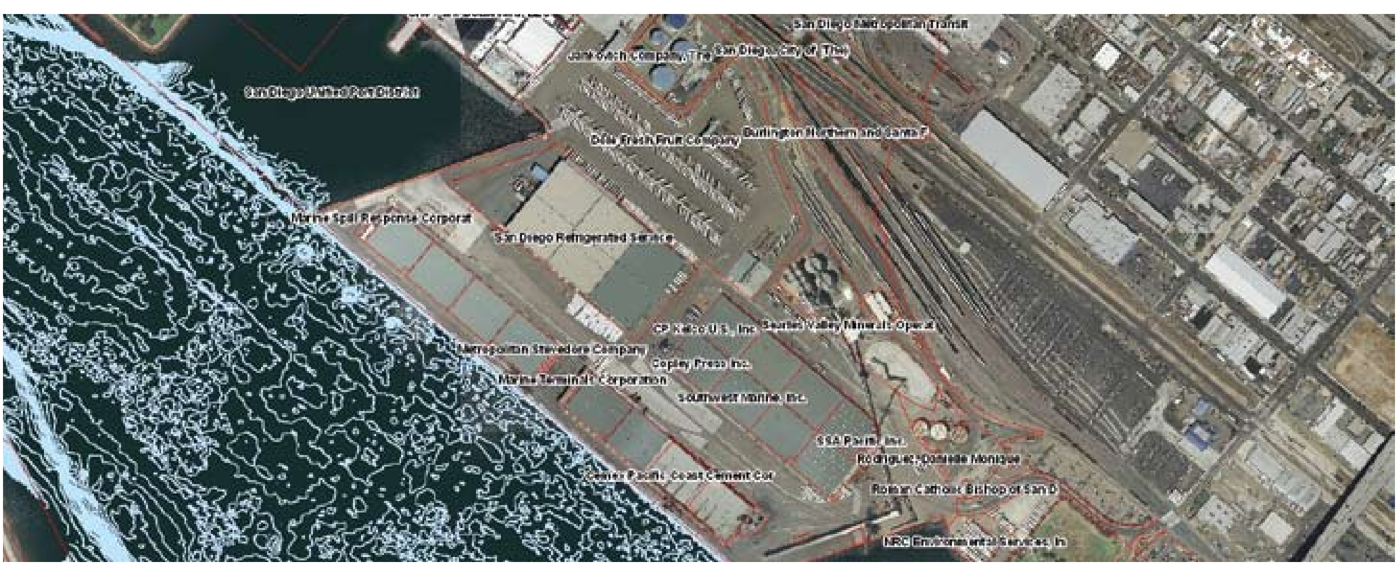

With GIS, the Port of San Diego can efficiently manage assets located on 6,000 acres surrounding San Diego Bay in California.

GIS Gives Port a Common Operating Picture

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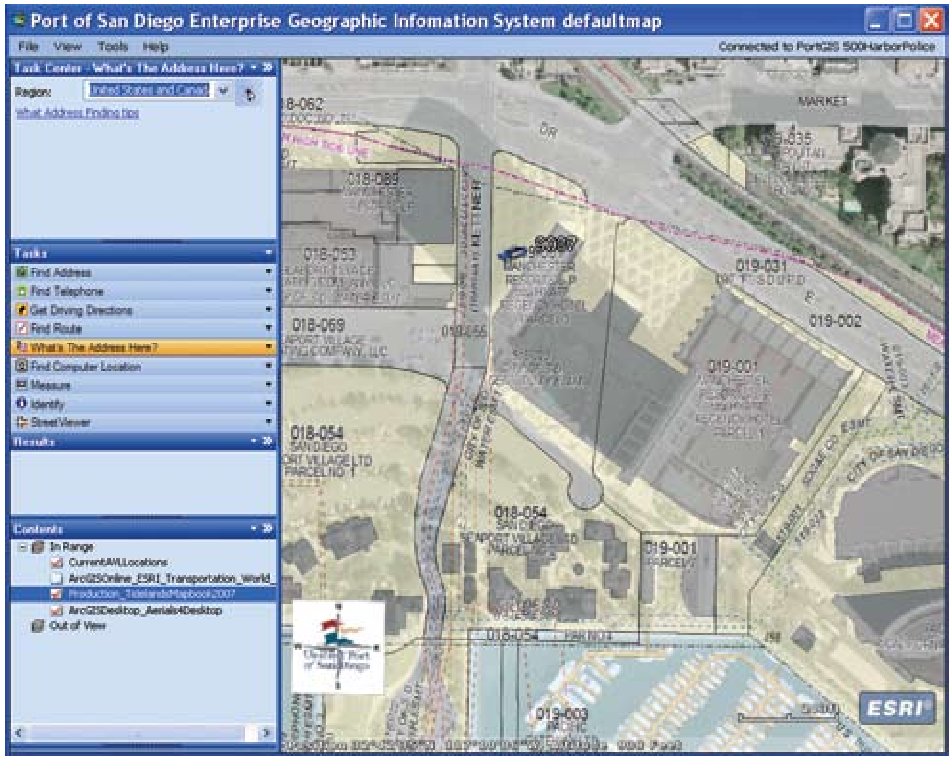
PortGIS Explorer is the most widely used GIS Web application. It gives staff access to high-resolution aerial photos and TideLands Mapbook.



GIS analyst Ari Isaak (left) and GIS coordinator Malcolm Meikle (right) review updates to the Port of San Diego's online GIS portal.

Ari Isaak, a GIS analyst for the San Diego District Port.

Creating an enterprise GIS has driven the implementation of data and file structure standards in the engineering department so CAD data can be seamlessly displayed and analyzed through the wide variety of ArcGIS Server clients. Web-based clients, accessible to all port employees, provide new tools for understanding the infrastructure the port manages and maintains. Users in engineering management and general services and asset managers in the real estate department also use these tools.

Moving data from CAD to GIS, CAD operators must follow naming conventions for drawings, layers, objects, and attribute blocks. The port adopted the United States National CAD Standard—which is used by organizations throughout the United States for exchanging building design and construction data—as a guideline for its own CAD data standards. The Department of Homeland Security Geospatial Data Model is used as a data model guide.

All scanned paper plat and record drawings are accessed by an intermediate table that contains relevant information about the documents that are stored in the geodatabase. Standardizing layer naming conventions for new drawings, as well as the creation of a master CAD drawing, means that engineering staff update those files instead of storing these drawings on local drives. This ensures that every department can understand and use GIS data. This has made attribution much easier, and CAD operators no longer need to guess how to describe features in the drawings.

Just Add Imagery

Another advantage of this system is the ability to view and use imagery in the CAD stations using the ArcGIS for AutoCAD tool. In the past, when engineers added TIFF images to AutoCAD—one at a time—the draw time was lengthy. If a drawing spanned more than one image, each image had to be loaded separately. This process was time consuming and frustrating for operators. "CAD designers love ArcGIS for AutoCAD if for no other reason than they finally have access to very high-resolution aerial [photos] quickly," said Isaak.

The port has two sources for imagery: .3-meter resolution aerial photographs from ArcGIS Online and 4-inch pixel resolution aerial photos flown in April 2009 by the port. The 4-inch resolution photos are used for quality control and as a source for creating new data. To use the aerials for these purposes, engineers must follow strict standards and use the same coordinate system employed by the GIS operators.

This simple change has been advantageous. Now, drawings can be viewed in the correct geographic space even if an image is not used as a backdrop. Drawings can also be located by performing a spatial search rather than by the name of a drawing. Now drawings can be used for more than one project. Previously, drawings had to be copied and pasted into work projects. These changes have cut down on the errors inherent in copying data and the amount of file space needed to store the drawings. Because the source data is managed in the GIS database, it can be used more than once. Now, everyone in the port is using the most accurate data.

Web-Based Enterprise GIS throughout the Port

"By using geographic data and systems, the port is able to use geography as the common factor to bring together data that otherwise is difficult to integrate," said Meikle. In 2007, when ArcGIS was adopted, the GIS group moved from the real estate to the information technology (IT) department. This allowed IT to manage and disseminate GIS data throughout the port. Access to the GIS data and system has empowered the port's employees to integrate their own independently developed workflows for managing spatial data and accomplishing their work using the information they need.

Departments that traditionally hadn't thought about using the port's facility information, such as the harbor police, are now users. Today, the harbor police employs two applications for tracking vehicles around port property—one desktop application built with ArcGIS Explorer and an in-car application that displayed map data in Web browsers that was created with OpenLayers, an open source JavaScript library.

Staff throughout the port can access the GIS through the PortGIS Resource Center. This central gateway to GIS information is accessed by clicking an icon on the port's internal Web home page. Here, staff can choose one of three Web applications—PortGIS Explorer, PortGIS Utilities, or PortGIS Projects—designed for various tasks and departments.

The most used GIS Web application is PortGIS Explorer. Staff can access high-resolution aerial photos and the port's TideLands Mapbook, which represents the port's overall geographic interests at the Port of San Diego. A user can navigate around the map to see exactly the information they need, turn on and off layers, and create maps to include in reports and e-mails. Data can be queried and measurements between two or more points obtained.

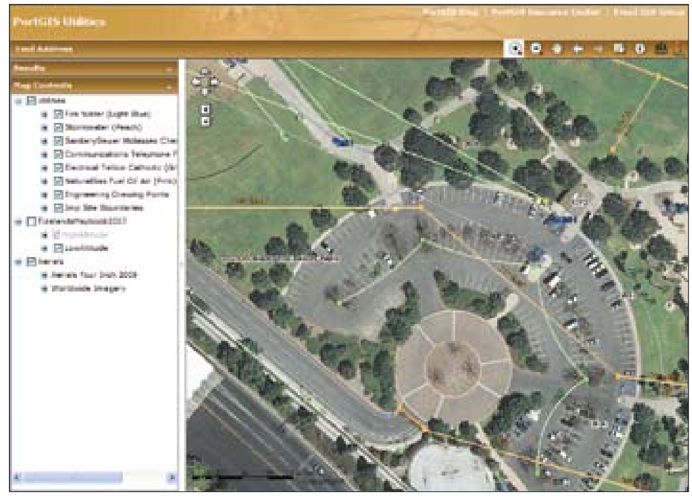
The PortGIS Utilities application focuses on current conditions. End users can view utility line work and access PDFs of official engineering drawings by location. This application furnishes all the functionality of PortGIS Explorer as well as georeferenced maps from important documents. PortGIS Utilities brings together the port's development effort affecting all the managed land and creates a common operating picture for departments as they move forward in their planning efforts. The PortGIS Projects application deals with future developments, the regulatory process, and obligations to which the port is committed.

Standards Make Workers More Efficient

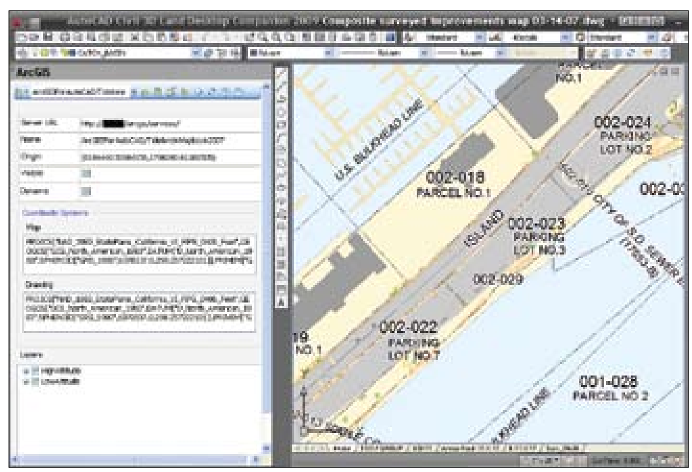
PortGIS Utilities is the central clearinghouse for the port's utilities data, including electrical, fire, natural gas, fuel, sanitary sewer, storm drain, telephone, water, chemical, fiber optics, and communication lines. The data is converted to ESRI feature classes using a batch file, which runs nightly. Instead of the engineers working with a traditional file system to structure the data, the data is spatially indexed so it can be more easily located. This also allows engineers to share data with the rest of the port. Simply having the data created using standards that are managed and shared from one location makes it much easier for staff to find answers.

The entire system was built using the Microsoft .NET framework, a file geodatabase, and Windows Server 2008 on a 64-bit machine. Clients were created using the .NET Web Application Development Framework (ADF) that comes with ArcGIS Server, which was customized using Visual Studio and incorporated many ideas from the .NET ADF Code gallery at the ESRI Web site. The IT department also created a streamlined method that assists users by installing software remotely. If staff members have questions, they can send e-mails to the IT department or check out a %scrachworkspace% (posdgis.wordpress.com/), a blog maintained by the port GIS professionals.

Today port staff can not only ask questions like How much square footage is available? but also reach further into the data by gaining access to official record drawings and viewing the relationship between a developer's plans and the geographic interests of the port. GIS is used in every department. It helps the harbor police track police cars. The general services department uses it for engineering data accumulation and maintenance. The finance department uses GIS to track money coming into the port by tracking corporate leases, maintaining parking meters, and other activities. Today the more than 600 employees at the



The central clearinghouse for the port's utilities data, PortGIS Utilities, enables engineers to find electrical, fire, natural gas, fuel, sanitary sewer, storm drain, telephone, water, chemical, fiber optics, and communications lines more easily and share the information with the rest of the port.



Using the ArcGIS for AutoCAD extension, engineers can bring GIS data into a familiar CAD environment and access GIS data whether it is created in-house or is accessed from ArcGIS Online.

port can use GIS data and Web-based applications.

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Visit the CAD Integration Resource Center (resources.esri.com/caddata). For more information on on ArcGIS for AutoCAD and to download the free extension, visit www.esri.com/arcgisforautocad.

The Accuracy and Precision Revolution

What's ahead for GIS?

By Jeffery S. Nighbert, U.S. Bureau of Land Management

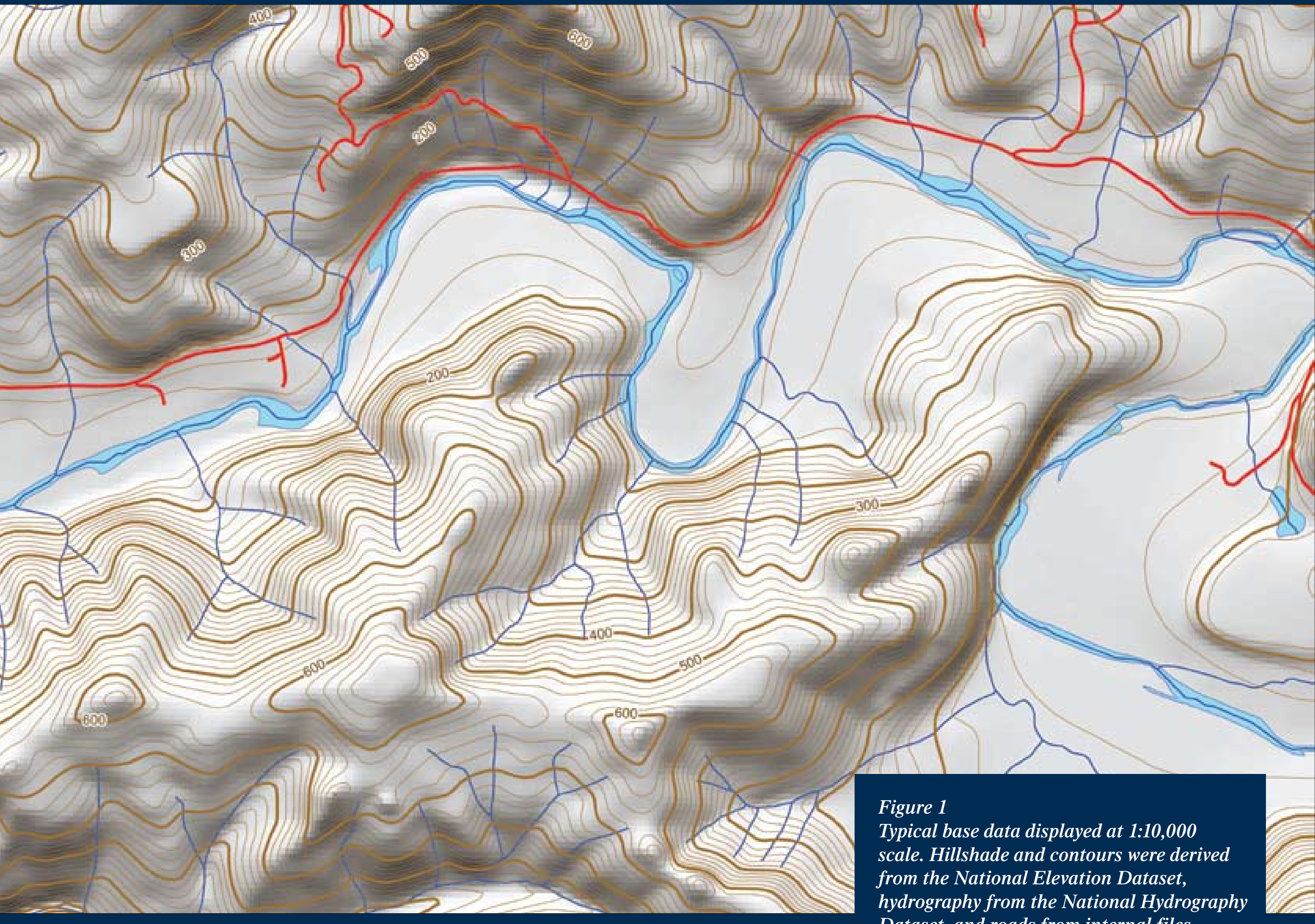
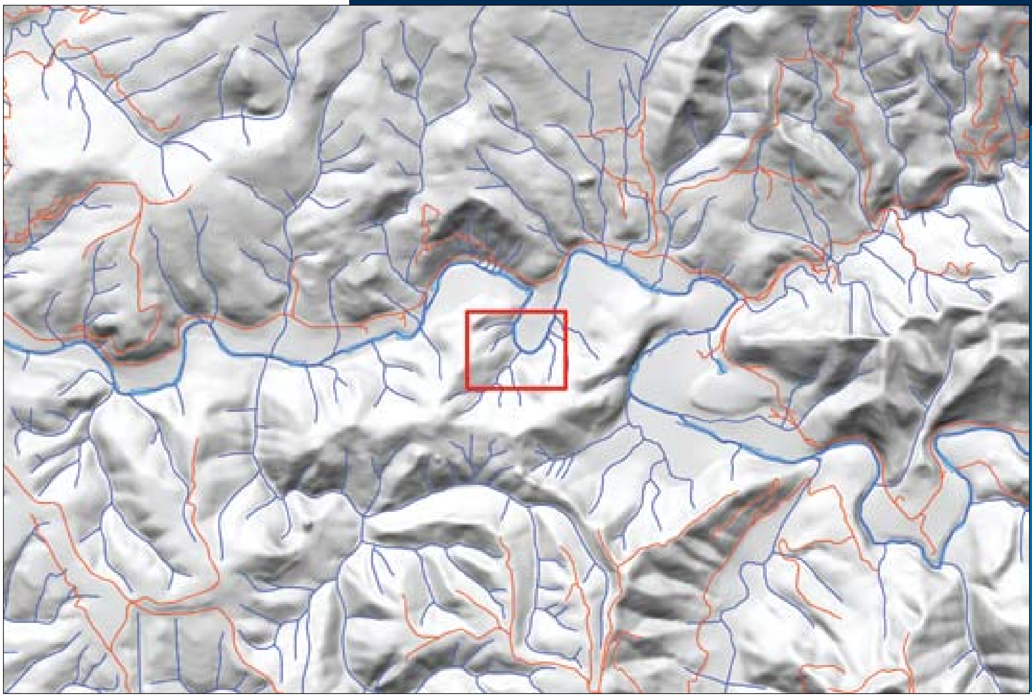


Figure 1
Typical base data displayed at 1:10,000 scale. Hillshade and contours were derived from the National Elevation Dataset, hydrography from the National Hydrography Dataset, and roads from internal files.

The ability to obtain precise information is nothing new. With great patience and skill, mapmakers and land surveyors have long been able to create information with an impressive level of accuracy. However, today the ability to determine and view locations with submeter accuracy is now in the hands of millions of people. Commonly available high-resolution digital terrain and aerial imagery, coupled with GPS-enabled handheld devices, powerful computers, and Web technology, is changing the quality, utility, and expectations of GIS to serve society on a grand scale. This accuracy and precision revolution has raised the bar for GIS quite high. This pervasive capability will be the driver for the next iteration of GIS and the professionals who operate them.

When I say there is a "revolution" going on in GIS, I am referring to the change in the fundamental accuracy and precision kernel of commonly used geographic data brought about by new technologies previously mentioned. For many ArcGIS users, this kernel used to be about 10 meters or 40 feet at a scale of 1:24,000. With today's technologies (and those in the future), GIS will be using data with 1-meter and submeter accuracy and precision. There are probably GIS departments—in a large city or metro area—where this standard is already in place. However, this level of detail is far from the case in natural resource management agencies such as Bureau of Land Management (BLM) or the United States Forest Service. But as lidar, GPS, and high-resolution imagery begin to proliferate standard sources for "ground" locations, GIS professionals will begin to feel the consequences in three areas: data quality, analytic methods, and hardware and software.

Figure 2
This is typical base data displayed at 1:24,000 scale. The hillshade and contours were derived from the National Elevation Dataset, hydrography from the National Hydrography Dataset, and roads from internal files. Red square indicates enlargement area for Figures 3 and 4.



Data Quality

As we try to integrate highly resolved data into existing GIS, the errors in legacy data will become more apparent. The expectation is that data is as accurate and precise as possible, so new geometry must be developed either through editing or by capturing new data. We will need to be more careful about documentation and mindful of appropriately mixing data in databases. The four figures accompanying this article illustrate the problems GIS professionals might encounter as they integrate more accurate data into GIS operations. For these illustrations, I used recently acquired lidar elevation data.

Figure 1 illustrates a typical base dataset displayed at 1:10,000 scale. Hillshade and contours have been derived from the U.S. Geological Survey National Elevation Dataset. The hydrography came from the U.S. Geological Survey National Hydrography Dataset. Roads were taken from BLM internal files. The standards of accuracy and precision of this data is typical of levels of the data used by natural resource management agencies such as the BLM and Forest Service. Most of the data used in these databases was originally derived from U.S. Geological Survey 1:24,000-scale topographic maps or from existing paper maps of lesser quality. Only in recent years has data been developed using GPS or heads-up digitizing from large-scale imagery or photography. Until recently, I considered the quality of this data pretty good since at commonly used scales ranging from 1:10,000 to 1:100,000, I could not readily detect any flaws.

Figure 2 shows hillshade and hydrography displayed at 1:24,000 scale, which is the intended scale of the data. The problem occurs when, because this is the highest resolution in the GIS, this same data is used for scales larger than 1:24,000. Note how hydrography matches the terrain (hillshade) in most areas.

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The Accuracy and Precision Revolution

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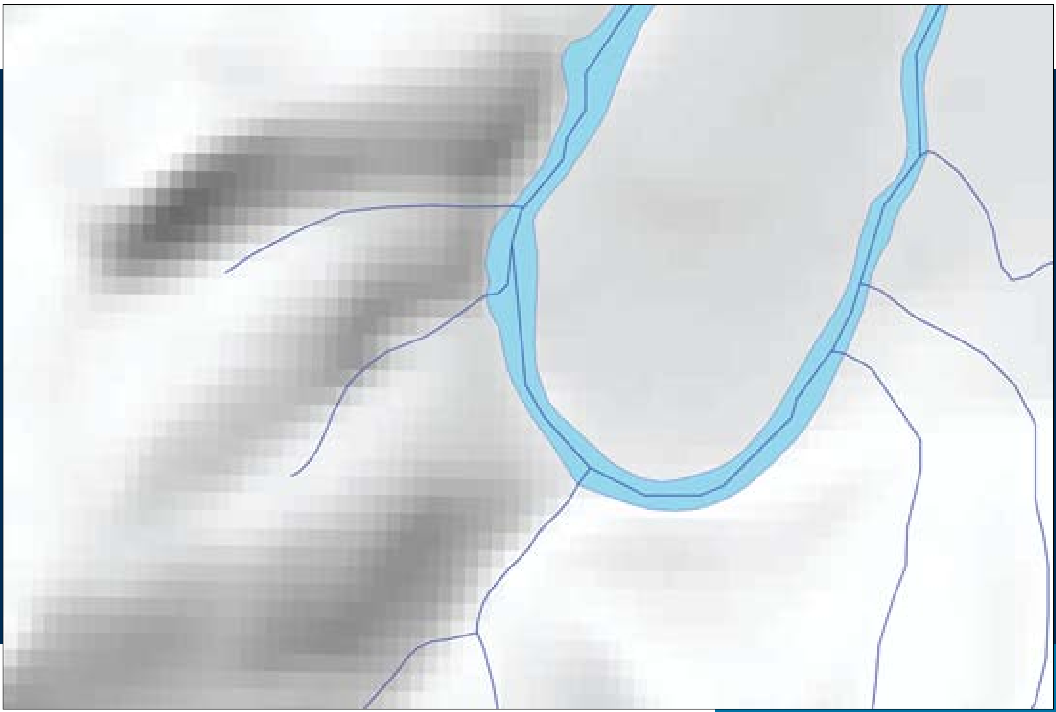

Figure 3
Hillshade and hydrography displayed at 1:24,000 scale. Note how hydrography matches terrain (hillshade) in most areas.

A red square surrounds the magnified areas in Figures 3 and 4 that show where flaws in the data become painfully apparent. For the most part, the hydrography follows the terrain in Figure 3 at a scale of 1:2,400 (about 1-meter resolution, which is the pixel size of the bare earth lidar data).

Figure 4 uses a hillshade of the bare earth lidar returns from 1-meter lidar data. In this figure, one can see how poorly the hydrography matches the terrain at 1-meter resolution. The hydro linework does not follow the drainages very closely. There are errors of omission. Where there should be line work, there is none, and there are errors where the line work simply is wrong.

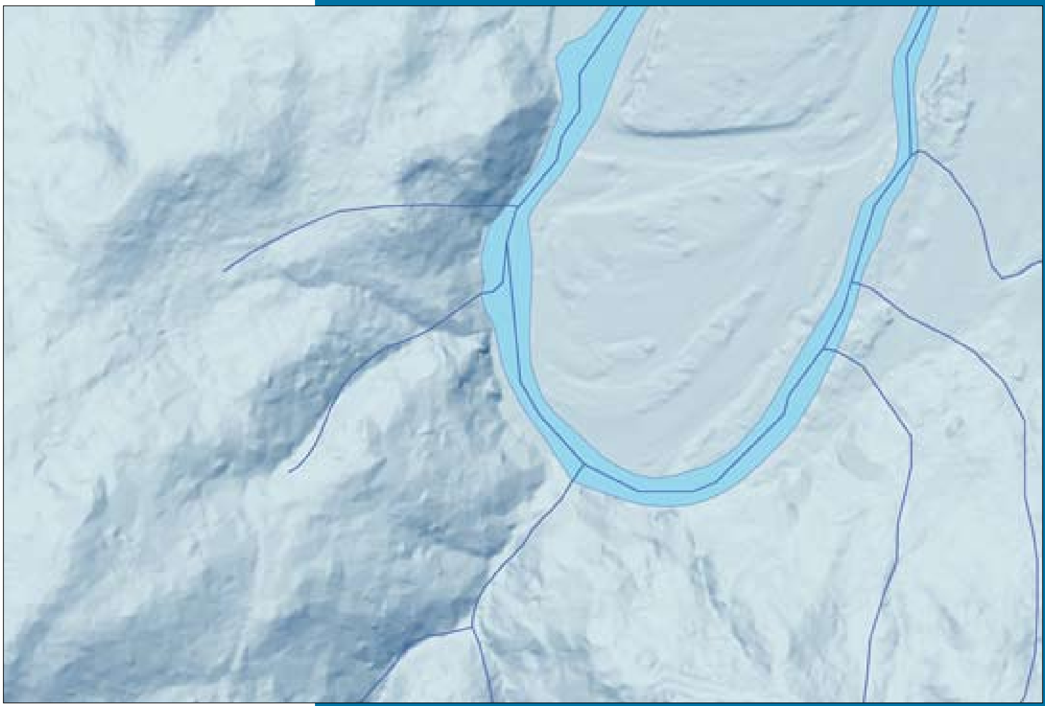

Figure 4
Enlarged area displayed at 1:2,400 shows slight discrepancies between hydrography and terrain.

Analytic Methods

Analytic methods will need to change as we learn to use data with greater detail and intensity. Processes that might have worked at 10-meter resolution will now need modification. Figure 5 illustrates the type of problems encountered when we attempted to automate stream generation on a half-meter digital elevation model (DEM) derived from lidar. The red line represents the stream drainage that should have been generated, while the darker blue line is what the program produced. The increased accuracy and precision caused the stream delineation program to send the course of the stream along the roadbed. Special programming had to be added to make automated watercourse line generation successful. (Note the white line represents

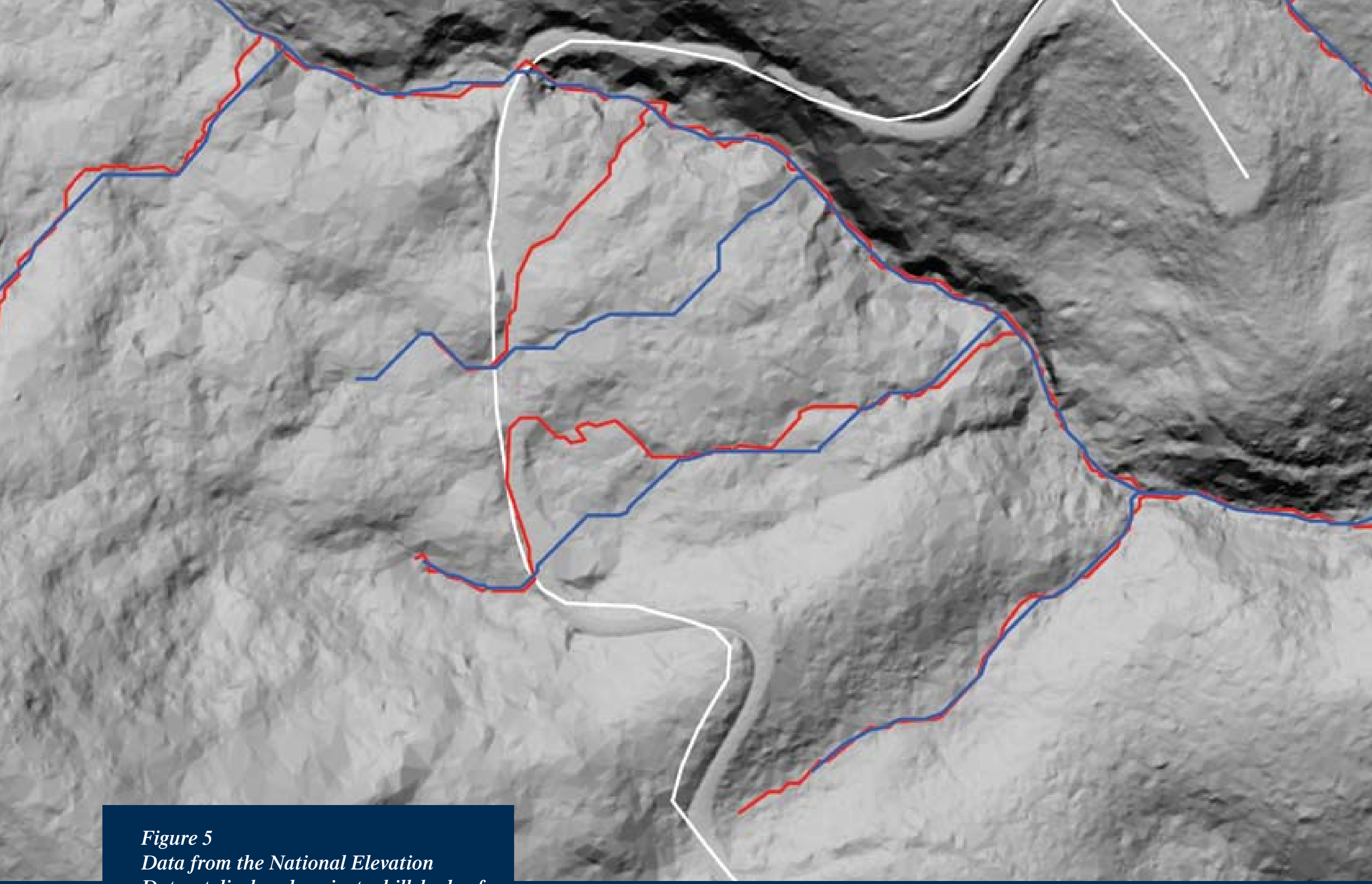

Figure 5
Data from the National Elevation Dataset displayed against a hillshade of lidar bare earth at 1:2,400. Notice many errors, discrepancies, and omissions.

a road from the BLM database that does not follow the roadbed as indicated by the lidar information.)

Hardware and Software

High-resolution GIS data is expensive to store, use, and manage. For example, a 1-meter resolution elevation model is 100 times larger than the equivalent area of a 10-meter elevation model. One-half-meter color imagery from the National High Altitude Photography program is actually 12 times larger than the equivalent area in 1-meter black-and-white images. Vector data collected at 1 meter between points could be 10 times larger than when collected using the 1:24,000 standard of 40 feet. For land management agencies, where GIS data represents broad expanses of administrative territory, the increased need for disk storage is huge.

Core processing memory and hardware capabilities requirements have also greatly increased. Increased requirements create problems when the size of the data exceeds the size of the maximum addressable memory space. You may have noticed this problem in vector functions such as overlay, dissolve, and union. Increased coordinate and pixel density also slows down response time and clogs up networks. Obviously, computer capabilities will need to keep pace!

There may be a rise in data service providers and the technology to support them: you may get your data from a third party via the Internet. New equipment and data management strategies will be needed to process such intense data.

New technologies can help us make the transition to the "new GIS data." We should be looking to cloud computing services. In simple terms, cloud computing is nothing more than Internet-based data or computer services that provide specific products to GIS. When you use ArcGIS Online, you are using cloud computing. However, services could provide lidar data or processing services to large groups of people, and this would allow smaller companies and groups to leverage the data while avoiding the expense of maintaining the in-house functionality.

Conclusion

As a GIS professional, I have spent most of my career striving to build and improve the accuracy and precision of GIS databases as well as the overall data quality of the BLM's information. The advent of higher accuracy and precision data is great news! For new GIS professionals, a tremendous and exciting time lies ahead as they begin building a new geographic foundation for the world.

Do not despair over small details and technical problems; they have a way of solving themselves over time. The bigger issue, of course, is how to use this new and better data to meet customers' needs. The current saying among GIS folks is to use the "best available" data. I am thinking a new mantra would be to use the "most appropriate" data.

About the Author

Jeffery S. Nighbert has been a geographer with the Bureau of Land Management for more than 30 years and is currently the senior technical specialist for GIS at the Oregon State office, located in Portland, Oregon. He has extensive experience in GIS and holds a master's degree in geography from the University of New Mexico.

Unit Testing for ESRI Developers

A test case for ArcUnit

By Brian Noyle and David Bouwman, DTSAgile

While some may hope that this column might define unit testing as a component of the software development process that we, as geo-developers, are allowed to ignore, our contention is that it is a critical component in any GIS software development effort. It is a facet of development that cannot be ignored.

An informal industry survey performed in 2008 by one of the coauthors of this column revealed that 48 percent of developers in the GIS industry do not write any unit tests. This statistic, when paired with the fact that maintenance costs for custom development projects typically exceed 50 percent of project life cycle costs, indicates that testing standards require a bit of attention in the GIS industry.

The basic principle underlying unit testing is simply to take the smallest executable segments of code—typically at the method level—and prove that the code works as expected under as many anticipated circumstances as possible. Most often this process is performed by writing code that can be repeatedly executed using an automated testing framework such as NUnit or MbUnit. While there are other methods, the primary reasons for this automated testing regimen are threefold:

- The developer must prove that custom code works.
- The developer must prove the overall design works (e.g., follows good OOP/OOD practices, separation of concerns, single purpose classes).
- The developer must have a concise and rapid means of tracking and managing regression as the code base evolves.

At the conceptual level, the unit testing process is very simple and is illustrated in Figure 1. In a typical scenario, a test class is written that instantiates a class to be tested. The test fixture class calls methods on the class under test and validates the results of those method calls. Most automated testing frameworks will prepare a report of test results so the developer can quickly identify and address problem areas in the code.

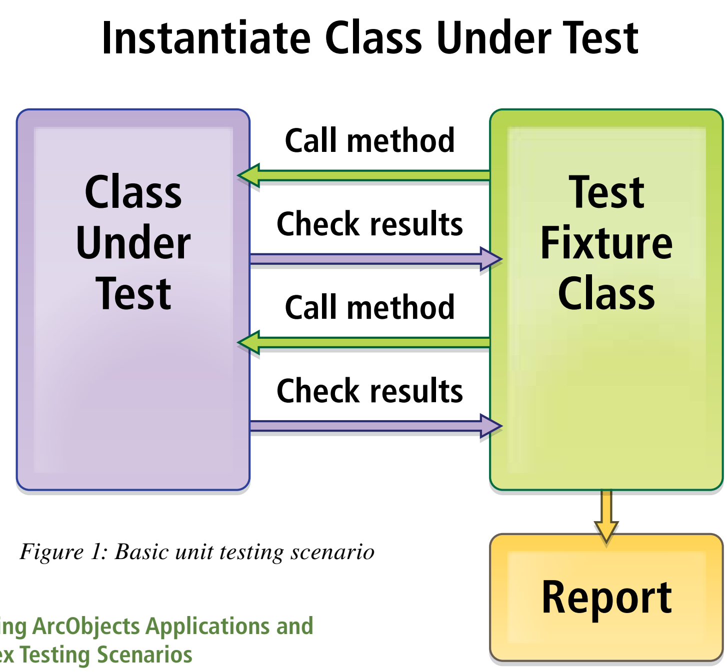

Figure 1: Basic unit testing scenario

Designing ArcObjects Applications and Complex Testing Scenarios

Simple methods with simple arguments mean simple unit test fixtures. Nearly everyone reading this article will understand that testing a summing function, a user authentication routine, or a method to fetch data is a relatively straightforward process. At the same time, testing complex methods that accept complex inputs results in complex test fixtures with results that are frequently difficult to reduce to a Boolean good or bad result.

While the authors work primarily in the Web realm on a daily basis, we have written literally hundreds of thousands of lines of ArcObjects code over the years and recognize the integral role such applications will continue to play in the GIS enterprise for the foreseeable future. Unit testing these applications is critical. Most ArcObjects code falls into the second, more complex, testing category. For example, how does the developer test that a custom edit sketch task returned a valid geometry or that the resulting geometry intersected with a target layer to return the correct number of features?

The first step in effective unit testing of ArcObjects applications is designing the application using patterns that facilitate unit testing from the start. In general this means following good object-oriented design patterns as shown in the diagram in Figure 2.

Methods should be single purpose and have no side effects or reliance on global variables (IApplication, for example). Wherever possible, application logic should be separated from eventing and the general "wiring" that makes the application go.

In the case of ArcGIS Desktop applications, the developer must be careful to separate ArcMap from ArcObjects. Keep custom code out of the ArcMap event handlers and encapsulate logic in business objects and utility classes that can be independently instantiated and tested. Conversely, keep event delegates and sinks out of your custom logic. Let's just all agree that ArcMap is going to raise that OnSketchFinished event and the .NET CLR is going to pass it off to your delegate. If they don't, what are you going to do about it?

Simply pass needed data into your custom classes from your unit test fixtures and validate what you have control over.

For stand-alone ArcGIS Engine and ArcGIS Server applications, the developer typically controls all the code so a custom app. will typically already contain code to create an instance of everything a unit test needs. While there is no IApplication lurking in the background to muddy the waters, validation of custom functions is still complex because we still need a way to validate a geometry or a feature class.

When developing applications for ArcGIS Server, custom code should be kept out of code-behind files and *.asmx files. This allows migration of custom components to the server object container (SOC) and will increase ease of unit testing.

Unit Testing Geometry Operations: A Test Case for ArcUnit

No matter how much we design for unit testing, we are still faced with the problems of how to collect the needed objects/data to pass in to a test method (feature class, geometry) and how to validate the results of the test (e.g., check that a given geometry result is correct). ArcUnit, a community-based open source project, provides tools and utilities to address this need. Currently hosted on Assembla at http://svn2.assembla.com/svn/arcdeveloper/TestingUtilities, the ArcUnit effort consists of a series of utility classes and tools designed and implemented to assist the developer in manipulating and validating data when unit testing ArcObjects code. These tools can be freely downloaded by developers who are encouraged to use the tools provided and contribute new functionality for the benefit of the developer community.

The ArcUnit code base has been started with tools and utility classes to unit test custom geometry editing functions. To date, the effort has focused on how to simulate sketches, store and retrieve geometries, and create tests against independent datasets not tied to a specific instance of a geodatabase. A custom ArcGIS Editor extension and toolbar are included in the source code, as well as utilities for serializing and deserializing ArcObjects and classes to simulate commonly

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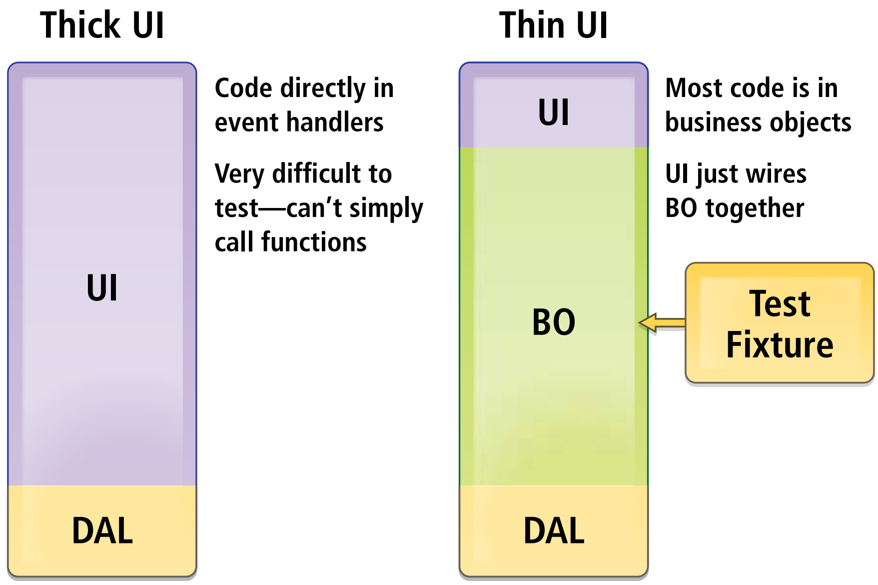

Figure 2: Proper abstraction of business logic away from UI and event handlers to facilitate testing

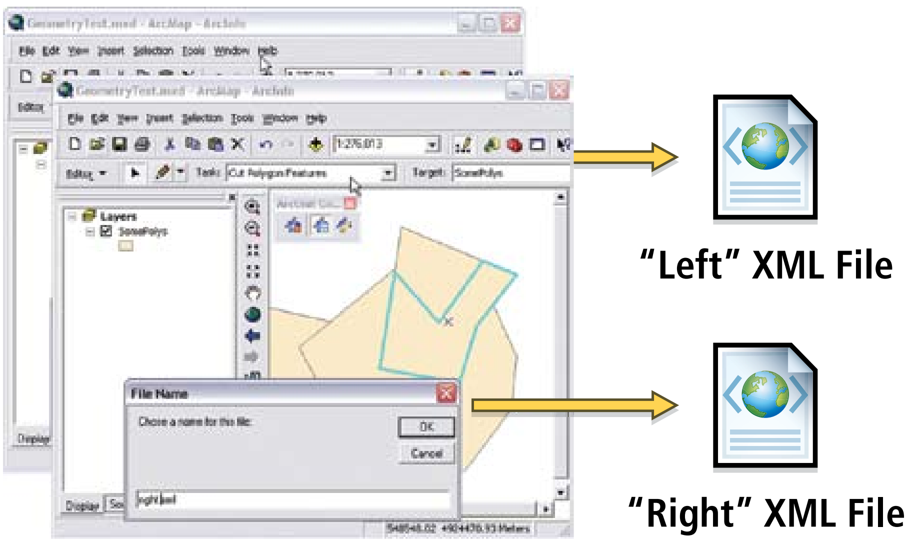

Figure 3: Using ArcUnit custom editing toolbar to serialize geometries for use in unit tests

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used ArcObjects interfaces such as IFeatureClass and IObjectClass.

Using ArcUnit

As a test case for illustrating how to use ArcUnit utilities, assume that a developer must validate a custom Split Polygon edit task in ArcMap. Using the design principles discussed above, the developer separates the implementation of the polygon split from the eventing in ArcMap. To test the custom logic of the split edit task, the developer now needs

- A source polygon to be split
- A polyline to be used to cut the source polygon
- The resulting "pieces" from the split operation to use for validation
- A series of invalid polylines to test negative split cases

How might the developer get the information required for effective unit testing without being tied to user interaction and a geodatabase instance? The answer lies in the IXMLSerialize interface. More than 200 ArcObjects classes implement this interface (including many aspects of the geodatabase), and any of these objects can be stored as an XML representation. A custom editing toolbar supplied in the ArcUnit source code allows a developer to serialize sketch geometries or selected geometries from a map and load/draw geometries from existing XML files as shown in Figure 3.

The basic workflow for unit testing geometry operations with ArcUnit is simple. Using the ArcUnit editing toolbar in ArcMap, needed geometries are created and serialized into XML files for use within unit test fixtures. The resulting XML files are then stored as embedded resources within the unit testing project inside a Visual Studio solution (illustrated in Figure 4), so that they are source controlled and have no dependency on user action within ArcMap or on a specific instance of a geodatabase.

To write unit tests to validate the geometry operations involved in the Split Polygon edit task test case, serialized geometries are loaded from resource files at test startup and passed-into a function under test from within an individual unit test, and output geometries are compared using IRelationalOperation::Equals(). The test source code example shown in Figure 5 leverages GeometryStorage and GeometryRelations utility classes included with ArcUnit to assist with serialization/deserialization and unit test assertions, respectively.

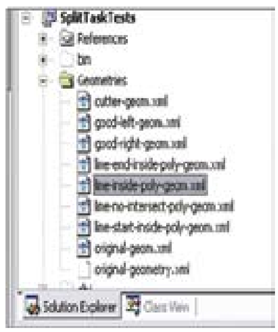

Figure 4: Captured geometries are serialized as XML and used as embedded resources in the test project.

Conclusion

The authors have generally found unit test coverage for custom GIS development initiatives within the ESRI realm to be comparatively low relative to other software sectors. In defense of the geodeveloper community, unit testing for ESRI applications presents a special case where typical spatial operations are complex and difficult to test without dependencies on the containing application, user interaction via the GUI, and geodatabase instances. We believe that unit testing is still a critical component of our custom development efforts and that the ArcUnit initiative can serve as a starting point for a whole host of mock objects, data serialization/deserialization routines, and test patterns that will assist the community in guaranteeing high-quality code against the ESRI COM-based APIs by providing a library of functions covering many common GIS testing scenarios.

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```
[Test()]
public void SplitPolygonTest()
{

    IGeometry cutter = GeometryStorage.RetreiveFromXml(GetXML("Geometries.cutter-geom.xml"));
    IGeometry original = GeometryStorage.RetreiveFromXml(GetXML("Geometries.original-geom.xml"));
    IGeometry goodleft = GeometryStorage.RetreiveFromXml(GetXML("Geometries.good-left-geom.xml"));
    IGeometry goodright = GeometryStorage.RetreiveFromXml(GetXML("Geometries.good-right-geom.xml"));
    //Call the function
    SplitPolygon output = geometryOperations.SplitPolygon((IPolygon) original, (IPolyline) cutter);

    //Compare the outputs
    Assert.IsTrue(geometryRelations.AreGeometriesSame(output.LeftGeometry, goodleft), "Left Geometry was incorrect", null);
    Assert.IsTrue(geometryRelations.AreGeometriesSame(output.RightGeometry, goodright), "Right Geometry was incorrect", null);

}

[Test(), ExpectedException(typeof(ArgumentException))]
public void SplitPolygon_LineInsidePoly()
{

    IGeometry cutter = GeometryStorage.RetreiveFromXml(GetXML("Geometries.line-inside-poly-geom.xml"));
    IGeometry original = GeometryStorage.RetreiveFromXml(GetXML("Geometries.original-geom.xml"));
    //Call the function
    SplitPolygon output = geometryOperations.SplitPolygon((IPolygon) original, (IPolyline) cutter);

}
```

Figure 5: Test source code for the Split Polygon edit task in the test case leverages GeometryStorage and GeometryRelations utility classes included with ArcUnit to assist with serialization/deserialization and unit test assertions, respectively.

About the Authors

Brian Noyle

Originally trained as a global change biologist and tundra botanist, Brian Noyle has nearly 10 years' experience as a GIS software developer and architect. His professional and technical interests are primarily focused on moving clients toward more standard architecture and development practices and patterns to facilitate a closer integration of GIS with the standard IT enterprise. Noyle has extensive experience in full software life cycle management with a focus on delivering through Agile project management methods. When he's not in the office, he can be found on his mountain bike, picking a bluegrass lick on a guitar, or standing in a river waving a stick at amused trout.

Dave Bouwman

Dave Bouwman has been designing and developing GIS software for the last 12 years with projects ranging from small Web sites to statewide enterprise forest management systems. Over the last few years, he has been leading a team of developers in the pursuit of great software built in a sane manner. The combination of an Agile process with pragmatic development practices taken from extreme programming has led to a highly optimized methodology of creating solid software that he and his staff are proud to put their names on. When not attached to a computer, Bouwman is often found mountain biking on the trails around Fort Collins, Colorado.

Versioning 101

Essential information about ArcSDE geodatabases

By Derek Law, ESRI Product Management

Editor's note: *Rather than a comprehensive discussion of versioning, this article presents the key concepts about ArcSDE geodatabase versioning including version creation; version workflows; reconciliation and post; states; and compress operations.*

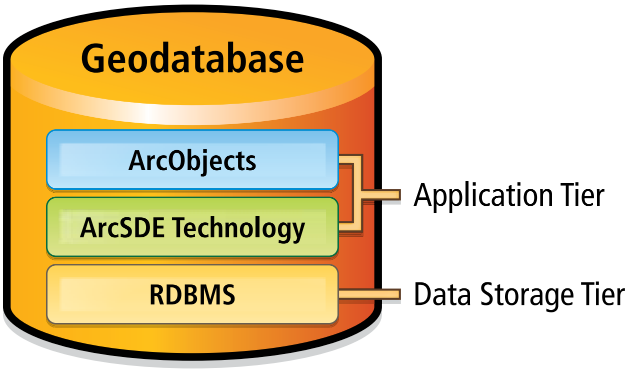

Figure 1: At a conceptual level, ArcSDE geodatabases have a multi-tier architecture that implements advanced logic and behavior in an application tier on top of a data storage tier. The application tier consists of ArcObjects and ArcSDE technology, while the data storage tier is comprised of database management system (DBMS) software. ArcSDE geodatabases utilize the simple, formal data model of a DBMS for storing and managing information in tables. They also leverage DBMS support for multiuser transaction processing.

What Is **Versioning?**

Versioning is the mechanism that enables concurrent multiuser geodatabase editing in ArcSDE geodatabases. It uses an optimistic concurrency data-locking model, which means no locks are applied to affected features and rows during long transactions. It is the default editing environment in enterprise ArcSDE geodatabases and supports complex editing workflows that are required by enterprise GIS systems.

Versioning records and manages states of individual features and rows as they are edited while preserving integrity in the database. It is the basis for multiple users accessing and editing data simultaneously in enterprise ArcSDE geodatabases. Conceptually, a version of the geodatabase represents an alternative, independent, persistent view of the geodatabase. It supports multiple concurrent editors and does not involve creating a copy of the data. A version references a specific state of the geodatabase. It contains all the datasets in the geodatabase and evolves over time. Users access data in an enterprise ArcSDE geodatabase through a version. Behind the scenes, simple queries in the underlying DBMS are used to view and work with the referenced state for a particular point in time or to see an individual user's current edits.

Note: Database transactions represent a package of work that makes changes to databases. Most database transactions occur within a very short time period, often within seconds. A state is a unit of change (i.e., an edit) that is performed on data in the geodatabase. It represents a discrete snapshot of the database whenever a change is made.

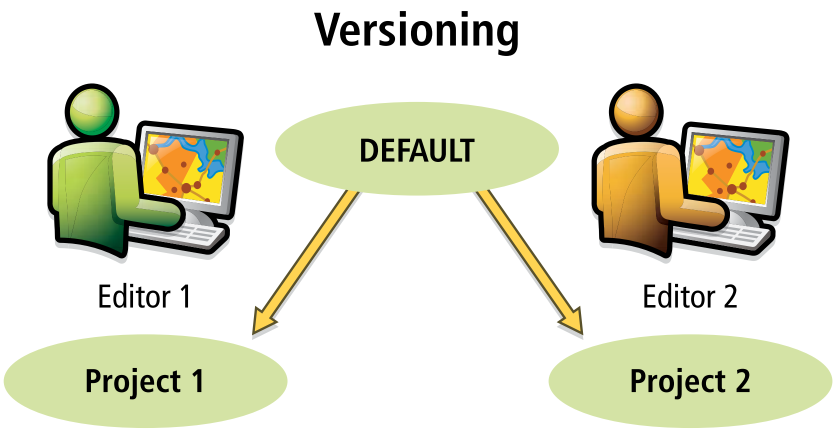

Figure 2: Versioning allows multiple users to work on the same geodatabase. DEFAULT is the parent version and Project 1 and Project 2 are child versions.

Enterprise ArcSDE geodatabases provide support for many users creating and maintaining large amounts of GIS data in a central location. In many cases, multiple users need to edit the same data at the same time. In other words, they require concurrent multiuser geodatabase editing. The nature of the spatial relationships and connectivity that define geographic data requires that edit sessions for geospatial data typically span long periods of time (e.g., hours, days, or weeks). These long edit sessions can be thought of as long transactions in the DBMS. Additional user requirements include the ability to undo or redo changes, the capability to develop alternative application design proposals without affecting the published geodatabase, and a mechanism to manage how the data and the geodatabase have changed over time.

The DEFAULT Version

Every enterprise ArcSDE geodatabase has a default version named DEFAULT that is owned by the ArcSDE administrator. The DEFAULT version always exists and cannot be deleted or renamed. It is the root version and, therefore, the ancestor to all other versions in the geodatabase. In many workflow strategies, it is the published version of the geodatabase, representing the current "public" end-user view of the geodatabase. The DEFAULT version is typically maintained and updated over time by incorporating changes to it from other versions. Like any other version, it can also be directly edited.

Enterprise ArcSDE geodatabases can have many versions. A new version (child version) is created from an existing version (parent version). When a new child version is first created, it is identical to its parent. However, over time, parent and child versions may diverge as changes are made to each version. In the figures in this article, Project 1 is a child version of DEFAULT, its parent version (Figure 2).

When editing geodatabase datasets within the versioned editing environment, each version will seem to have its own copy of the data. As a dataset is edited in one version, it will appear differently when viewed in another version. Regardless of how many versions exist within the geodatabase, each dataset is only stored once in the DBMS. Behind the scenes, ArcGIS leaves each dataset in its original state during editing. All changes to a dataset are recorded in associated tables known as delta tables. Delta tables are also commonly called the A (adds) and D (deletes) tables. Each table or feature class will have an associated pair of these delta tables when they are registered as versioned within ArcCatalog.

Every version has an owner, description, parent version, associated database state, and level of user access. There are three levels of access to a version:

- Private: Only the owner can view and edit.
- Protected: All users can view, but only the owner can edit.
- Public: All users can view and edit.

The access level for the DEFAULT version is public by default. It is recommended that its access level be set to protected to ensure data in an enterprise ArcSDE geodatabase is not accidentally corrupted or lost. This means that only the ArcSDE administrator can edit or post changes to the DEFAULT version.

Versions are beneficial for workflow management in enterprise ArcSDE geodatabases, such as modeling different discrete stages in a GIS project (e.g., each stage is represented by a version) and modeling what-if scenarios without affecting the original datasets. They provide a framework for security management and quality assurance in data editing, and they also support historical archiving and geodatabase replication.

Versioning Workflows

Versioning supports many complex editing workflows and can be easily adapted and/or customized to meet the business requirements of any organization. Three example business workflows using versions are shown in Figure 3. The simplest workflow is to have concurrent editors directly editing the DEFAULT version (see Figure 3A). Another option is to create a separate version (e.g., multiple projects) for each editor in the geodatabase (see Figure 3B). To ensure that the publication view of the geodatabase is protected from accidental data corruption, many organizations create a quality assurance (QA) version from the DEFAULT version (see Figure 3C). The QA version would be maintained by a data quality manager and would regulate all edits that are applied back to DEFAULT. Note that each versioning workflow strategy has its own advantages and disadvantages. It is important to use a strategy that best meets the requirements of the business workflow.

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Database States and Versions

A version references a specific database state—a unit of change that occurs in the database. Every edit operation performed in the geodatabase creates a new database state. An edit operation is any task or set of tasks (e.g., additions, deletions, or modifications) undertaken on features and rows. State ID values apply to any and all changes made in the geodatabase.

Initially, the DEFAULT version points to state 0. As edits are made to datasets in the geodatabase, the state ID will increase incrementally. In general, the state ID increases by a value of one for each edit operation. However, there are some exceptions where state ID may increase by a value greater than one, such as during a reconcile operation.

Figure 4 illustrates the state ID increasing as edits are made to two feature classes in the geodatabase. An edit session is started on a polygon and a point feature class in the DEFAULT version (see Figure 4A). A new polygon feature is added (see Figure 4B). Next, an existing point feature is deleted (see Figure 4C). Lastly, an attribute property for two polygon features is modified in one operation, then the edit session ends and edits are saved (see Figure 4D). For each edit, the state ID incremented by a value of one. The DEFAULT version now points to state 3.

In the previous example, the geodatabase state ID increased because editing was performed through the DEFAULT version. If the scenario had included another edit session with another version, the state ID would have also grown by the number of edits performed in the second edit session.

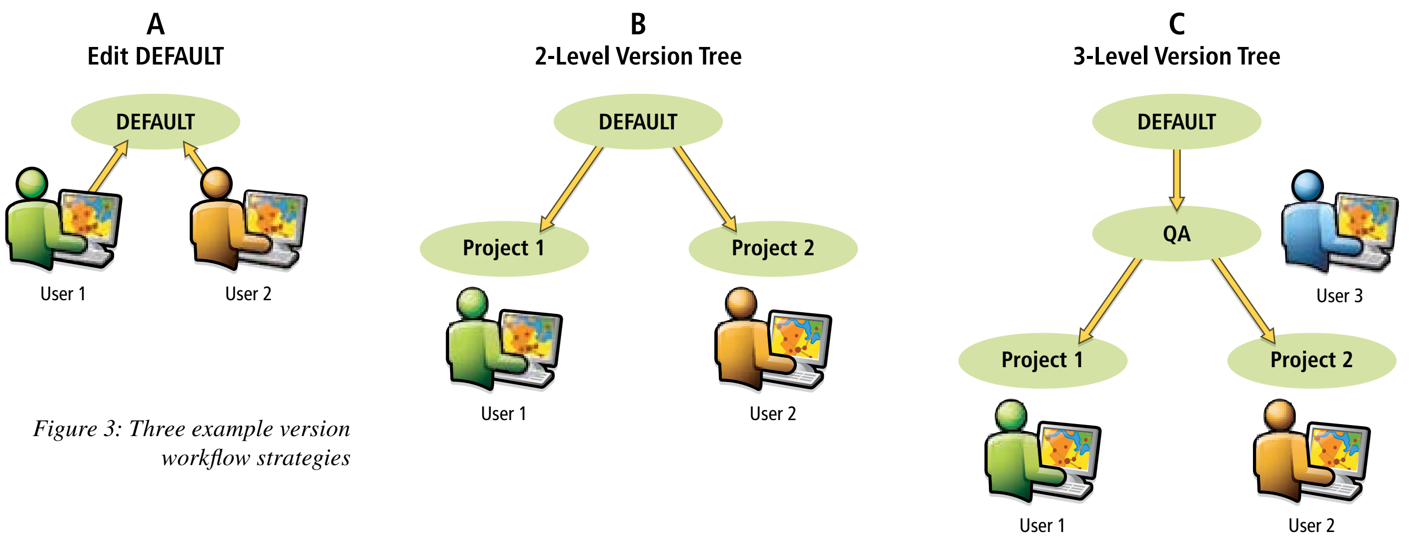

Figure 3: Three example version workflow strategies

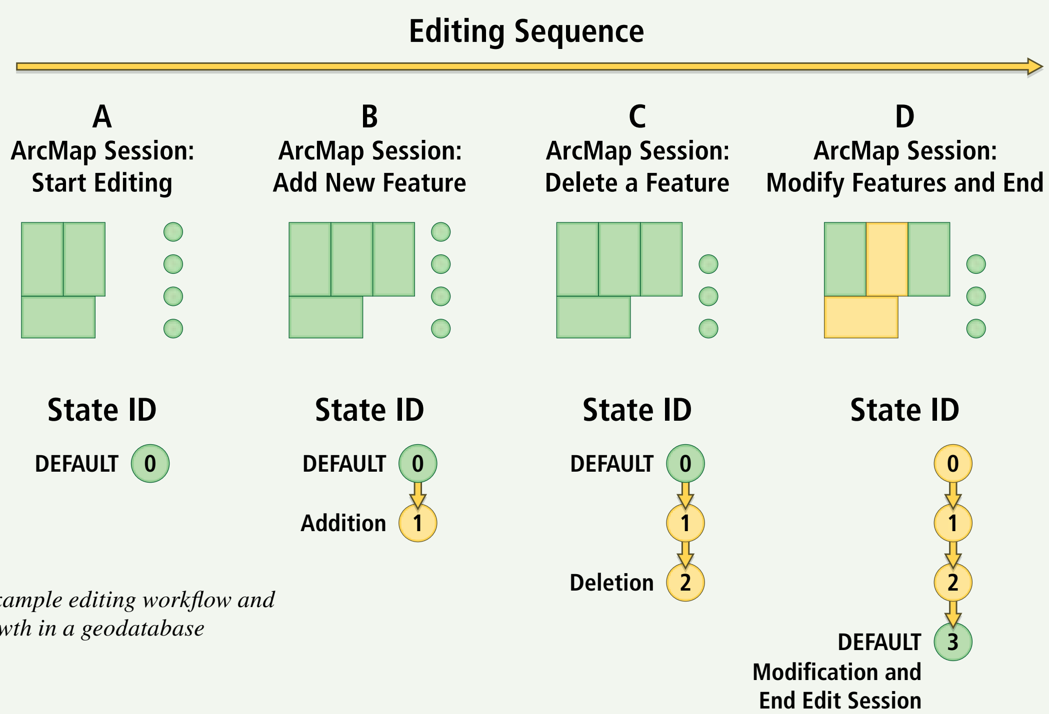

Figure 4: Example editing workflow and state ID growth in a geodatabase

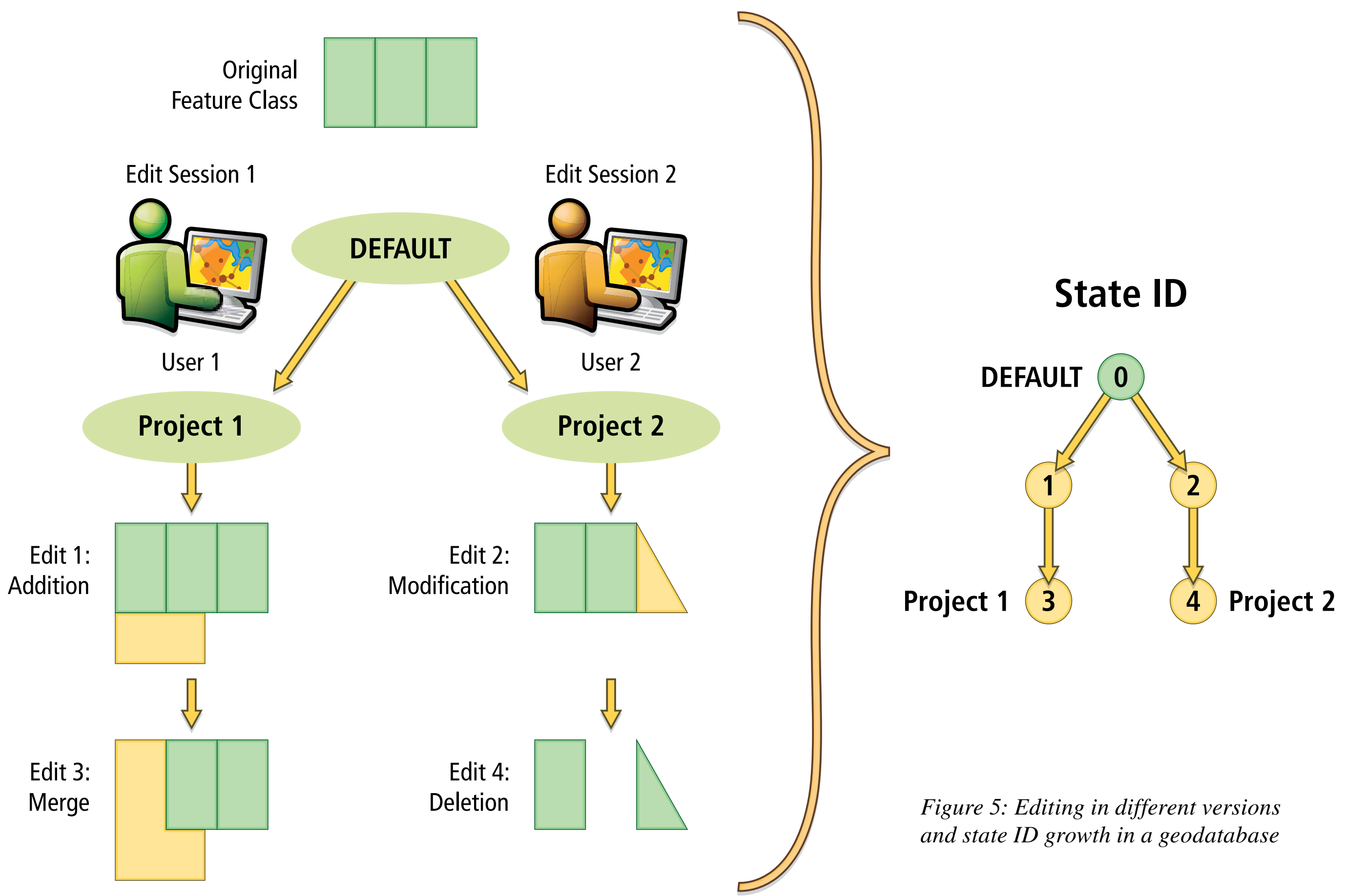

Figure 5: Editing in different versions and state ID growth in a geodatabase

Figure 5 illustrates a two-level version tree editing workflow. Two versions (Project 1 and Project 2) were created from DEFAULT. Initially, they were both exactly the same as DEFAULT and pointed to state 0. As User 1 starts an edit session and adds a new feature, the state ID increases by one. When User 2 begins an edit session, a new separate branch is created from DEFAULT to record edits. In this scenario, these editing operations occur as follows:

1. User 2 modifies an existing feature.
2. User 1 merges two features into a single feature.
3. User 2 deletes a feature.

The order of these edit operations is recorded with corresponding state IDs that represent each change made in the geodatabase.

State IDs in the geodatabase can be conceptually thought of as being maintained in a treelike structure. This structure, called a state tree diagram, is a logical map between states in a geodatabase. As the geodatabase is edited over time, a lineage of states is maintained that identifies all the changes that have occurred in a version. To determine the lineage for a specific version, follow the most direct path up the state tree to state 0.

At the end of the example in Figure 5, DEFAULT points to state 0. Project 1 points to state 3 and has a lineage of 3, 1, 0; and Project 2 points to state 4 and has a lineage of 4, 2, 0. Version parent-child relationships can be derived from the state lineages. Both the Project 1 and Project 2 versions reference newer state IDs in contrast to DEFAULT, and their lineages contain the state ID that DEFAULT references: state 0. This indicates that DEFAULT is likely an ancestor version to them. In this case, DEFAULT is the parent version to both Project 1 and Project 2.

Version Management

The number of versions that exist within an enterprise ArcSDE geodatabase can be seen in the Version Manager dialog box in ArcCatalog and ArcMap (as shown in Figure 6). Version Manager will show all versions in a geodatabase, except those marked as private—those versions will only be visible to their respective owners.

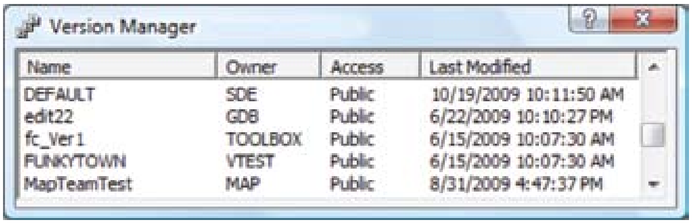

Figure 6: Version Manager dialog box in ArcGIS

Versions can be created or deleted from the Version Manager dialog box. As stated earlier, it is important to implement a versioning workflow strategy that best fulfills the requirements of the business workflow. The complexity of managing versions in a geodatabase increases as more versions are used.

Edits that are made within a version are isolated to that version until its owner or the ArcSDE administrator decides to merge the changes into another version. The exception to this statement is schema changes. When the schema in a version is changed—for example, by adding a new field to a table—the change applies to all other versions. The operational task of properly merging edits between versions in an enterprise

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ArcSDE geodatabase is achieved in ArcGIS through two operations: reconciling and posting. These two operations are typically performed in tandem (i.e., reconciling followed by posting) to combine edits from one version with another version.

Reconcile

Reconciling is the first step in merging edits between two versions. In this process, edits from an ancestor version (called the target version) are brought into the version being edited in an edit session in ArcMap (called the edit version). A target version can be any version in the direct ancestry (i.e., in the lineage) of the version being edited. For example, referring back to the state tree diagram in Figure 5, DEFAULT is an ancestor version to Project 1, because DEFAULT points to state zero (0), which is part of Project 1's lineage: 3, 1, 0. The reconcile process involves merging edits from the target version into the edit version, as shown in Figure 7.

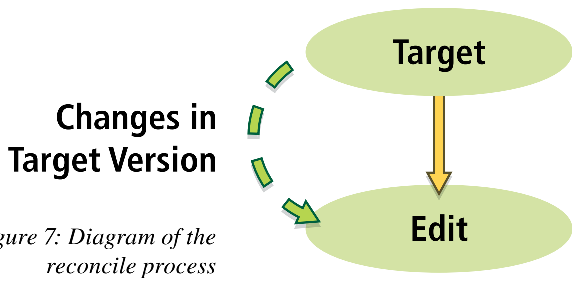

Figure 7: Diagram of the reconcile process

To perform a reconcile operation, there can only be one user editing the edit version. Since a version spans all the versioned objects in the geodatabase, any features or rows that were modified in the target version will be merged into the edit version. As the majority of these features and rows are not likely to be in conflict, they will merge seamlessly into the edit version. For example, if a new polygon feature was added in the target version, after the reconcile process, the polygon feature would appear in the edit version. The editor would then decide whether to save the changes in the edit version.

At a conceptual level, a reconcile process involves merging edits from one branch of the state tree with a different branch of the state tree. Figure 8 shows an example reconcile operation between two versions: QA and a child version of QA, Project 1. When Project 1 is initially created, it is the same as QA. An edit session is started on QA, a new feature is added, and that edit is saved. Next, a separate edit session is started on Project 1 and a new feature is added, but those changes are not saved yet. The editor for Project 1 then performs a reconcile process with the QA version, with QA as the target version and Project 1 as the edit version. All features that have been added, deleted, or modified in the QA version will be brought into the Project 1 version.

The reconcile process can occur either implicitly or explicitly.

- Implicit—A reconcile operation will occur implicitly when there are multiple editors editing the same version (see Figure 3A). Each editor maintains his or her own branch in the state tree for the duration of an edit session. When an editor attempts to save the edits in his or her edit session, a reconcile operation occurs to push the edits in the editor's branch to the branch currently referenced by the version. With multiple editors in one version, each time edits are saved, the reconcile process is executed. There is no choice of when the reconcile operation happens; it always occurs when edits are saved.

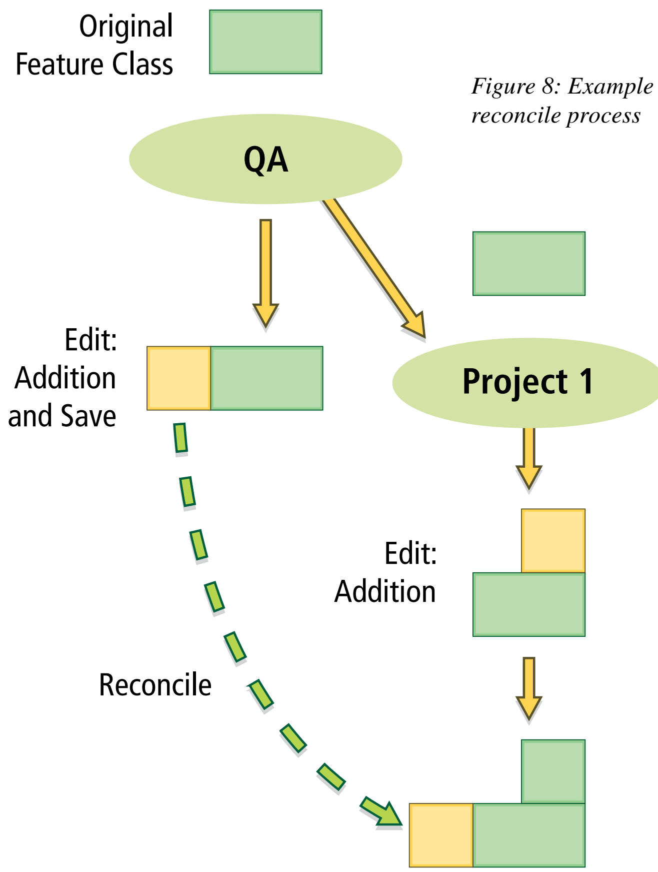

Figure 8: Example reconcile process

- Explicit—When performing a reconcile operation between different versions (as shown in Figure 8), an editor chooses when he or she wants the reconcile process to be executed. This differs from an implicit reconcile process, which occurs when edits are saved.

Regardless of how reconciliation occurs the mechanics are the same. The difference between implicit and explicit reconcile processes is when the reconcile process occurs and how the conflict detection options are specified.

Possible Conflicts during Reconciliation

In some cases, a small percentage of features and objects may be in conflict when comparing the target version and the edit version. Conflicts can occur in two editing scenarios: when the same feature is updated in both the target and edit versions or when the same feature is updated in one version and deleted in the other.

In practice, conflicts will not be encountered frequently for most reconciliation operations, because in many business workflows, versions typically represent different projects with distinct geographic areas (e.g., editing different areas of a map). Therefore, the likelihood of conflicts occurring is rare. Conflicts usually arise when editors are editing features that are in close proximity.

When performing a reconcile operation, ArcGIS finds conflicts in one of two ways: by object ID or by attribute. Conflict by object ID means that a feature is identified to be in conflict when any part of it (e.g., geometry or attributes) has been edited in both the target and edit versions. Conflict by attribute means that a feature is identified to be in conflict only when the same attribute (e.g., the same attribute field) has been edited in both the target and edit versions.

Default conflict resolution policies can be set to automatically resolve conflicts in favor of either the target version or the edit version. There is also the option to have the editor of the edit version resolve detected conflicts manually, by reviewing each conflict using the interactive Conflicts Resolution dialog box in ArcMap. Each conflict can be closely examined, and the editor decides whether to apply the target version edit, keep the edit version edit, or revert the feature to its state at the beginning of the edit session (i.e., the common ancestor state). After all conflicts (if any exist) are resolved, the reconcile process is considered completed and the editor can save edits and continue editing or proceed with a post operation.

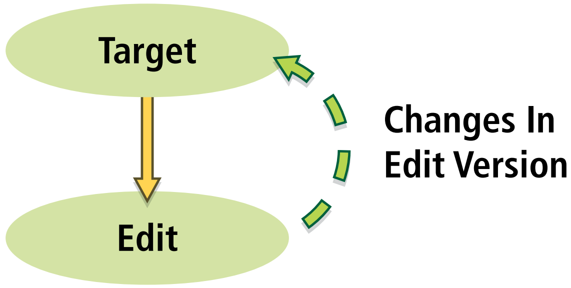

Figure 9: Diagram of the post process

Post

This is the second step when merging edits between two versions. This process must always follow a reconcile operation. A post process synchronizes the current edit version with the target version. All edits made in the edit version are saved into the target version, making both versions identical (see Figure 9).

Unlike a reconcile process, posting cannot be undone once it is performed because the changes are applied to a version outside of an edit session. Figure 10 conceptually illustrates a post operation between the QA and Project 1 versions. The post operation is performed immediately following the reconcile process previously discussed and shown in Figure 8. After posting, the new feature added in Project 1 (edit version) is merged into the QA version (target version). At the end of the reconcile and post workflow, both the QA and Project 1 versions will have the same view of the geodatabase. In other words, they are considered to be identical. At this point, the editor of Project 1 has the option to continue to make more edits in the edit session, then perform another reconcile and post process to synchronize the two versions or simply save edits and stop the edit session on the Project 1 version.

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Compress

Over time, an actively edited enterprise ArcSDE geodatabase typically accumulates hundreds of thousands of state IDs (representing edits stored in delta tables) and a deep and complex state tree. This can negatively impact performance. Periodically, the ArcSDE administrator must compress the ArcSDE geodatabase to remove any states not referenced by a version. A compress operation can reduce the depth of the state tree and helps maintain performance.

Compressing an ArcSDE geodatabase never removes data that is accessed through a version's lineage. It cleans up only unused data. A compress operation is implemented as a series of potentially large DBMS transactions that remove and renumber states inside one database transaction to ensure that the DBMS can restore the geodatabase to a consistent

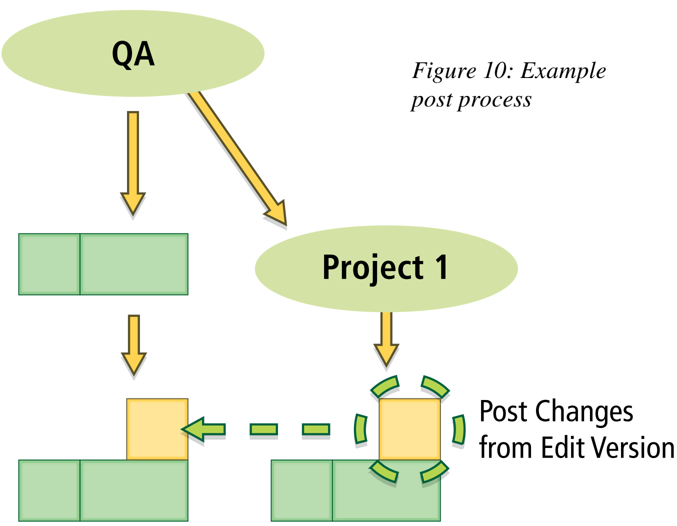


Figure 10: Example post process

state. Figure 11 shows what happens to the state tree when a geodatabase is compressed. Before the compress operation, there are three versions: DEFAULT, Project 1, and Project 2, which reference states 0, 3, and 4, respectively. A compress operation removes states that are not directly referenced by a version (states 1 and 2 in this example) and deletes them from the state tree. The edits they reference in the delta tables are also removed. Unused data in the geodatabase is deleted. A compress also moves entries in delta tables common to all versions into the base tables, reducing the amount of data the DBMS will need to search through for version queries. Both actions help maintain performance in the geodatabase.

Other Editing Models

At the 9.2 release, two additional editing models were added to ArcSDE geodatabases: nonversioned editing and versioned editing with the option to move edits to base. Nonversioned editing enables users to perform edits directly on the base tables of geodatabase datasets. It is analogous to a standard database transaction model for editing geospatial data.

Versioned editing with the option to move edits to base enables users to perform versioned editing as discussed in this article but also supports some nonversioned editing functionality. This editing model functions like regular versioned editing except when editing the DEFAULT version. When the DEFAULT version is edited through this editing model,

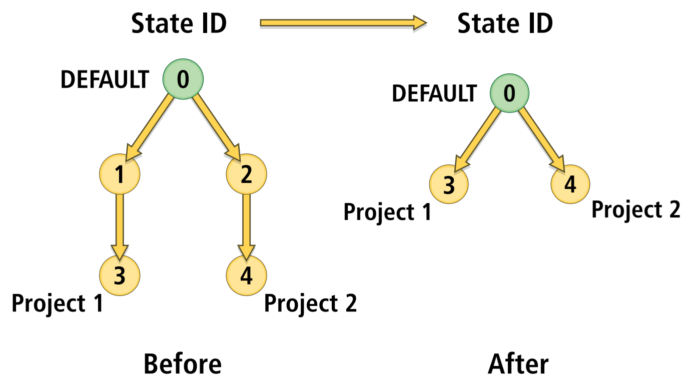


Figure 11: State tree diagram before and after a compress operation

changes are made directly to the base tables of geodatabase datasets. Also, when versions are reconciled and posted back to the DEFAULT version, edits in the delta tables are moved to the base tables.

Both editing models have some limitations on the types of datasets that can be edited and do not support geodatabase replication. More information on both editing models can be found in the ArcGIS Desktop Help Online documentation.

Conclusion and Resources

This article discussed the main concepts related to versioned editing in an ArcSDE geodatabase. It presented many of the common terms and concepts regarding concurrent multiuser editing in ArcSDE geodatabases. Versioning is the framework that supports historical archiving and geodatabase replication functionality. When implementing versioned editing, it is important to select the versioning workflow that best meets the organization's business requirements.

For more detailed information on the mechanics of how versioning works in an ArcSDE geodatabase, read the ESRI white paper *Versioning*, available from support.esri.com.

For more background on how state trees behave in versioned editing, read ESRI Knowledge Base article #32352—FAQ: How does the state tree change during an edit session? also available from support.esri.com.

For more examples on versioning workflow strategies, read the ESRI white paper titled *Versioning Workflows,* also available from support.esri.com.

For some tips and tricks on versioning, listen to the ESRI Instructional podcast *ArcSDE: Top Five Versioning Myths* available on esri.com.

Under Construction

Building and calculating turn radii

By Mike Price, Entrada/San Juan, Inc.

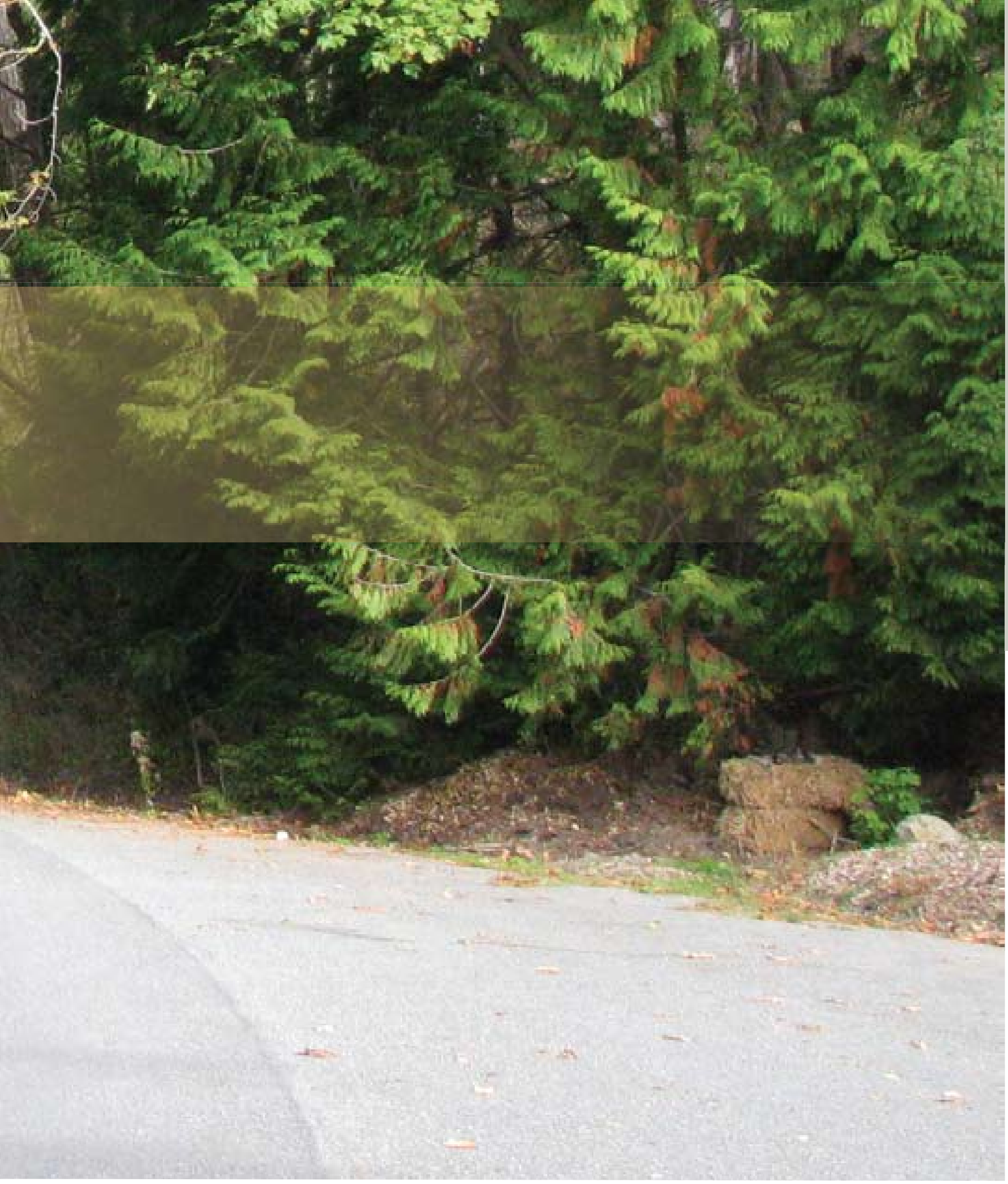
Fog Lines and Tangents

Past exercises in this series used speed limits, global turns, and slope to modify transportation network travel times. This exercise addresses the need for modeling tight turns on narrow winding roads when mapping rural, mountainous terrain.

Although I challenged my students at Bellingham Technical College to develop a fast, repeatable way to calculate radii for turns on existing mountain roads, we hadn't made any progress until one day last spring. I was driving home from a meeting where radius turns were discussed when my eyes began following the fog line on the right side of my highway travel lane. In Washington state, the fog line helps a driver track the roadway edge during limited visibility. I was fascinated by the way the line would appear straight, then curve, then straighten again. Sometimes, the line would even transition from a curve to the left, to a curve to the right, and back to a left curve again, without straightening.

I thought I might be onto something. I realized that if I could map these inflection (or tangent) points through each curve, ArcMap would calculate the length of its connecting chord. I also thought that I could use ArcMap to model and measure the distance from the turn chord to the farthest point away from the line and even calculate the travel distance around the curve.

After trying all types of geometric constructions using circles, ellipses, and irregular curves, I discovered a simple formula that required only the chord length and the perpendicular distance from the chord to the maximum curve extent (a line called the Middle Ordinate). I tried this formula on several curves, and it worked. On the Internet, I found the same formula on several engineering sites. I realized that it would be possible to draw and measure these lines in ArcMap and use this simple formula to determine the radii of a number of curves.



What You Will Need

- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- Sample dataset downloaded from *ArcUser Online*

An Overview of the Exercise

This exercise introduces a heads-up methodology for constructing and measuring line segments and calculating turn radii on a carefully digitized road centerline. In the next portion of the workflow, the road is broken into curves and straight lines. Once each curve contains its own radius, travel restrictions and impedance parameters may be developed and used for response modeling.

This methodology consists of five tasks.

Task 1: Identify and assign the start and endpoints of each curve—the point at which the road polyline transitions from straight to curved or tangent.

Task 2: Construct a two-node polyline (the Chord) to connect the curve points. Calculate its length in project units and assign each chord a unique, sequential number.

Task 3: Construct the Middle Ordinate, a two-node line perpendicular to the Chord, and intersecting the curve at its farthest point from the Chord. Assign a unique number for each curve in the Middle Ordinate table and calculate its length.

Task 4: Break the road polyline into curves and noncurves. Calculate the lengths of all road segments and assign each curve a turn number matching its Chord and Middle Ordinate.

Task 5: Join the Chord and Middle Ordinate tables to road segments. Populate the Chord and Middle Ordinate length fields for each curve. Finally, apply the curve radius formula to calculate the radius of all curves and make a map.

The Study Area: Chuckanut Ridge

Chuckanut Ridge is a private, gated community on Chuckanut Mountain in Bow, Washington, an unincorporated community in northwestern Skagit County. It is the second Firewise USA Community *[Firewise Communities/USA, recognized by the National Fire Protection Association, are small, cohesive neighborhoods and towns within the Wildland/Urban Interface acknowledged for homeowner involvement and commitment to minimize home loss to wildfire.]* organized in Washington state. Chuckanut Ridge Road, a single hard-surfaced 16-foot-wide road, accesses a handful of private homes scattered up the mountain. It starts at Chuckanut Drive and climbs from an elevation of 160 feet to nearly 1,600 feet in just 3.5 miles. Its average slope is nearly 11 percent, and its many twists and turns include at least 20 switchbacks or sharp S-turns. In addition, some curves actually tighten within a turn, creating an additional driving hazard.

Skagit County Fire District 5 provides fire and emergency medical service to Chuckanut

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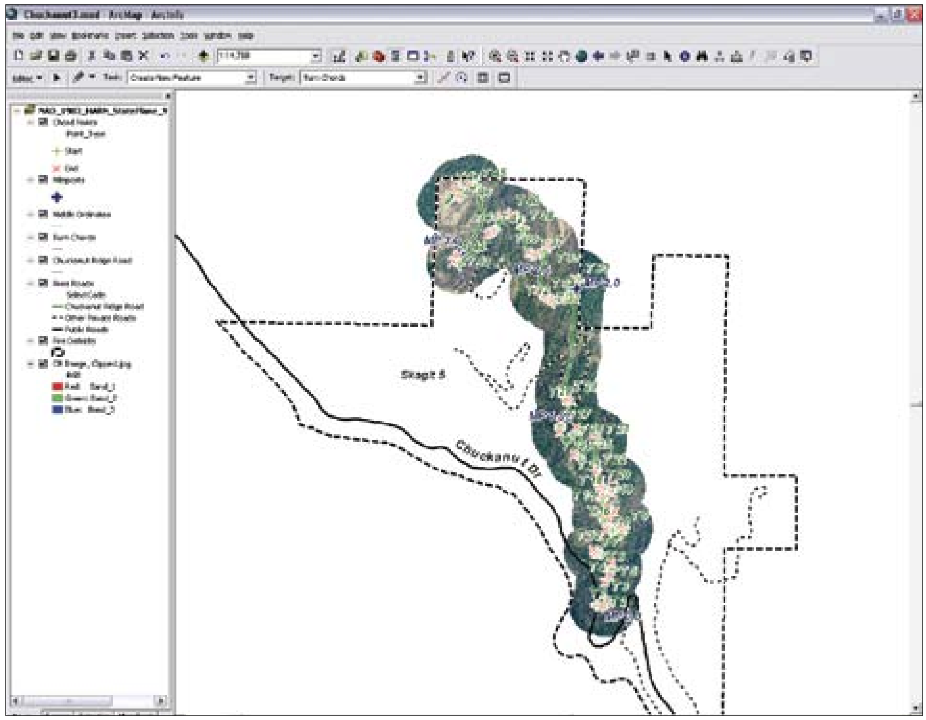
Ridge. The district built a new satellite station and is outfitting a specially designed fire engine for response up the steep hillside and along Chuckanut Drive.

Getting Started

To start this project, download the sample dataset (Chuckanut.zip) from *ArcUser Online* at www.esri.com/arcuser. Store this file near the root directory of the drive and extract the data and allow the creation of subfolders. Open ArcCatalog and navigate to the new Chuckanut folder. Inspect the shapefiles that will be used for this exercise.

This data is registered in Washington State Plane North American Datum of 1983 (NAD83) High Accuracy Reference Network (HARN) North Zone. Units of measure are U.S. Survey Feet. Notice that there are also several layer files that will be used to reference and symbolize data.

Preview the attribute tables for Chords1.shp and MidOrd1.shp in ArcCatalog and verify that both tables contain no values and are ready to hold the results of calculations. Navigate to \Chuckanut\JPGFiles\WASP83NFH and inspect the background image. This graphic was registered, resampled, and clipped from a high-resolution image provided by Skagit County GIS. Although it is pixilated, this image can make the relationships between residents, vegetation, and the access road more apparent.



This exercise was simplified by preselecting tangent points for the 47 significant curves on Chuckanut Ridge Road.

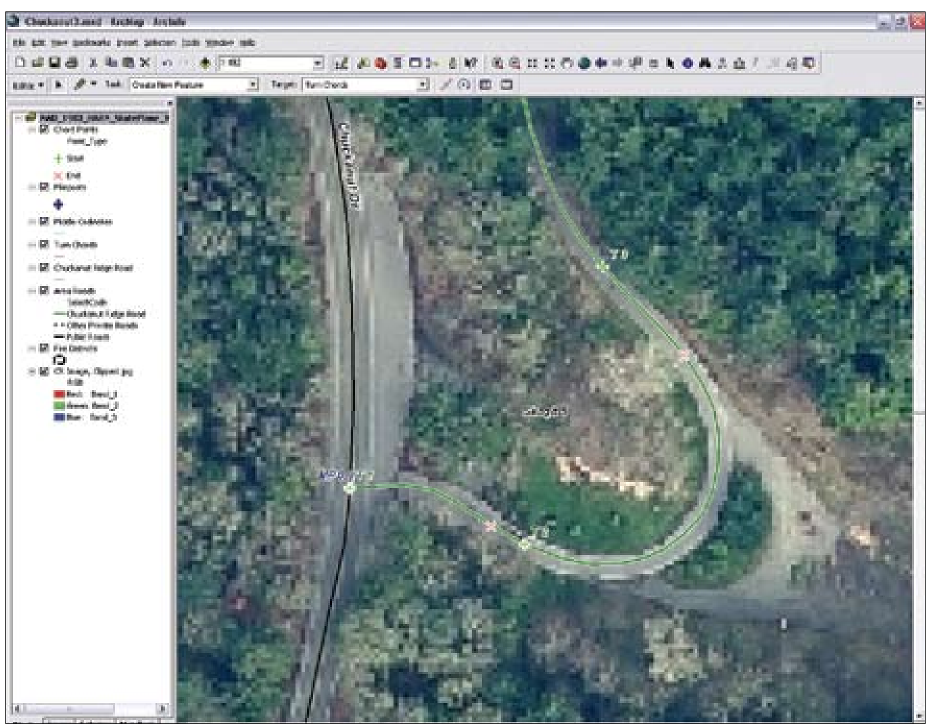
Task 1: Understanding Curves

Describing the curves on Chuckanut Ridge Road will require locating the points on both ends of each curve where the road centerline transitions from straight to curved. In a node-based polyline, this location is best represented by a single vertex where succeeding line sections are no longer lined up. If this curve were ideal, a straight line would touch it at only one point; the line would be tangent to the curve. In practice, although few curves are ideal, it is still possible to visually select two vertex points for each curve where the tangent begins and ends.

This exercise was simplified by preselecting tangent points for the 47 significant curves on the road. These points include start and end attributes and are numbered from 1 to 47.

1. Start ArcMap and open \Chuckanut\Chuckanut1.mxd. Fire District 5, area roads, Chuckanut Ridge Road, and its mileposts are all displayed over an aerial image of the study area. Zoom in and look around.

2. Navigate to \Chuckanut_Safe\SHPFiles\WASP83NFH and load the Chord Points,



To zoom to the beginning of Chuckanut Ridge Road, select the CR MP 0.0 1:500 bookmark.

Turn Chords, and Middle Ordinates layer files. Open the table for each layer and notice that the Chord Points table is fully populated while the other two tables are empty.

3. To make navigating around the map easier while working the exercise, several bookmarks were added to the map document. From the Standard menu, choose Bookmarks > Manage and select CR MP 0.0 1:500, located at the bottom of the list. The map zooms to the beginning of Chuckanut Ridge Road.

Notice that the road contains many vertices, typically spaced less than 20 feet apart. Modeling these curves requires carefully densifying the polyline. Carefully inspect the road centerline and observe how the Chord Points are placed. These Chord Points will be connected in the next section to build Turn Chords. Save the project.

Task 2: Constructing Chords

1. Choose View > Toolbars > Editor to load the Editor Toolbar and start an edit session. In the Editor toolbar, set the task to Create New Feature and make Turn Chords the target. On the Editor toolbar, in the Editor drop-down menu, choose Snapping and set the snapping layer to Chord Point vertices. In the Editor drop-down menu, choose Options and set the Snapping tolerance to 50 map units.

2. To build the first chord, activate the Sketch tool and use the cursor to snap to Chord Point T1, the green crosshair located at MP 0.0. Extend the line to the next red "x" and double-click to terminate the chord. Notice that it will be immediately labeled with zero values. Continue moving up the road, building Chord 2.

3. Hold down the C key to access the Panning tool and move along the road. To speed up this process, use the mouse wheel to zoom in and out. Build each chord in order from T1 to T47. The chords will be numbered to match the Chord Points so build them sequentially. When finished building the chords, turn off the background image and inspect them.

4. The next step is to add a Turn Number and the chord length. Open the Turn Chords table and verify that the FID field contains a continuous series of values that starts with 0 and ends with 47. If the FID values are not in a continuous sequence, renumber the chords to match the Turn Point series.

5. Right-click on the Turn_No field and choose Field Calculator. Use the Field Calculator to number the chords by using the simple formula [FID] + 1 to populate the Turn_No field. Make

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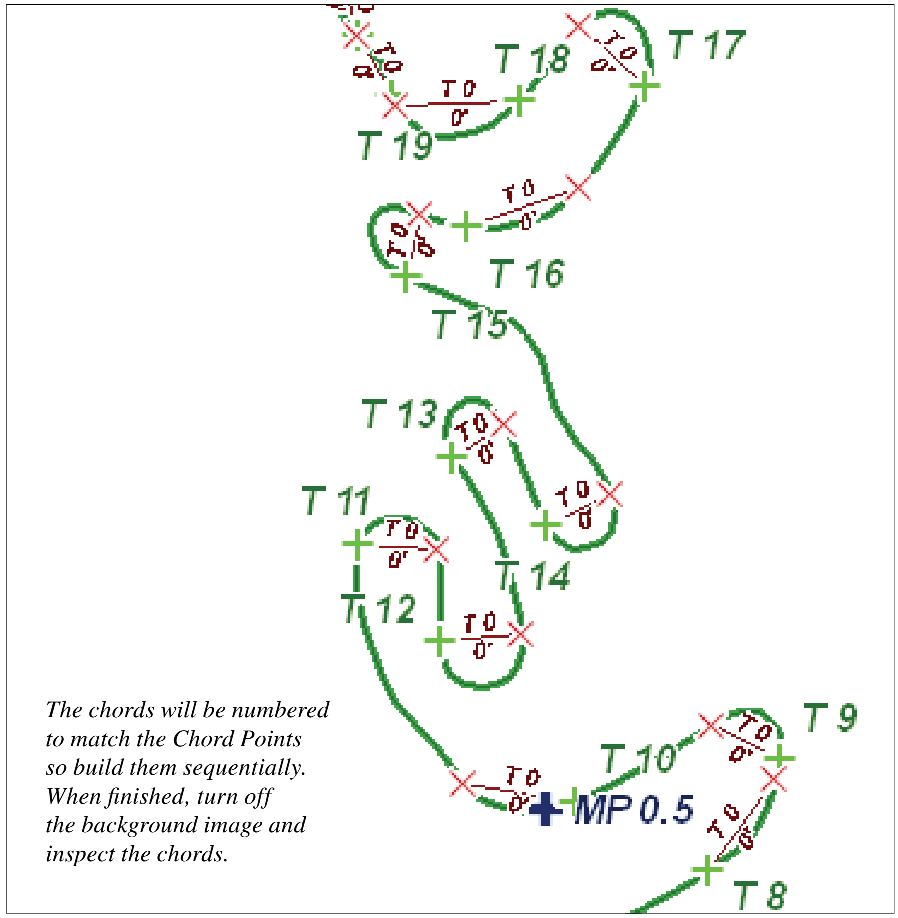
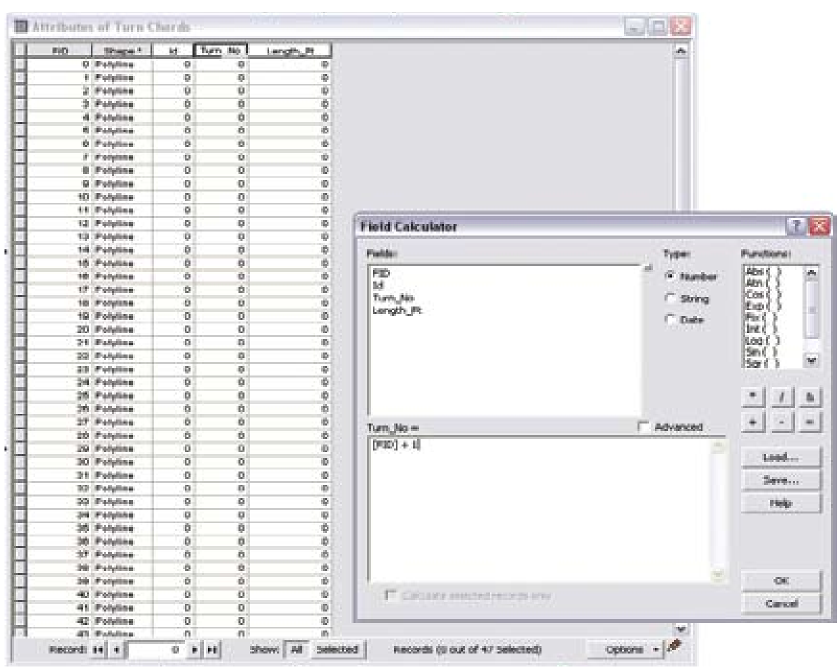


The chords will be numbered to match the Chord Points so build them sequentially. When finished, turn off the background image and inspect the chords.



Use the Field Calculator to populate the Turn_No field by numbering the chords using the simple formula [FID] + 1.

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sure the box next to Calculate Only Selected Fields is unchecked. These chord lengths will be joined to the road set, so make sure the numbers begin with 1 and end with 47.

6. Now, let's calculate each chord's length in U.S. Survey Feet. Right-click on the Length_Ft header and choose Calculate Geometry. In the Calculate Geometry dialog box, set Property to Length, use the coordinate system of the data source, and choose Units to U.S. Feet. Notice that this operation yields length values rounded to two places. These values appear on the map just below each turn number.

7. Make sure all the numbers are in order and that lengths are reasonable and save the map. Don't end the edit session because the next step is building the Middle Ordinates.

Task 3: Modeling the Middle Ordinate

In a perfect curve, the Middle Ordinate is a two-node polyline extending perpendicular from the Turn Chord to the farthest point out on the curve. Use the CR MP 0.0 1:500 bookmark to return to the extent at the beginning of Chuckanut Ridge Road.

1. On the Editor toolbar, change the Target from Turn Chords to Middle Ordinates. Keep Create New Feature as the task.

2. Under Snapping in the Editor toolbar, check the boxes for Turn Chord edge and Chuckanut Ridge Road vertex. Since the Middle Ordinate is often very short, change the Snapping tolerance to five map units.

3. Starting with Turn 1, use the Sketch tool to draw a polyline connecting the farthest point on the curve to the Turn Chord. Slide the second point along the chord until it appears perpendicular. Double-click to save the feature. Continue up the road, building a Middle Ordinate for each curve.

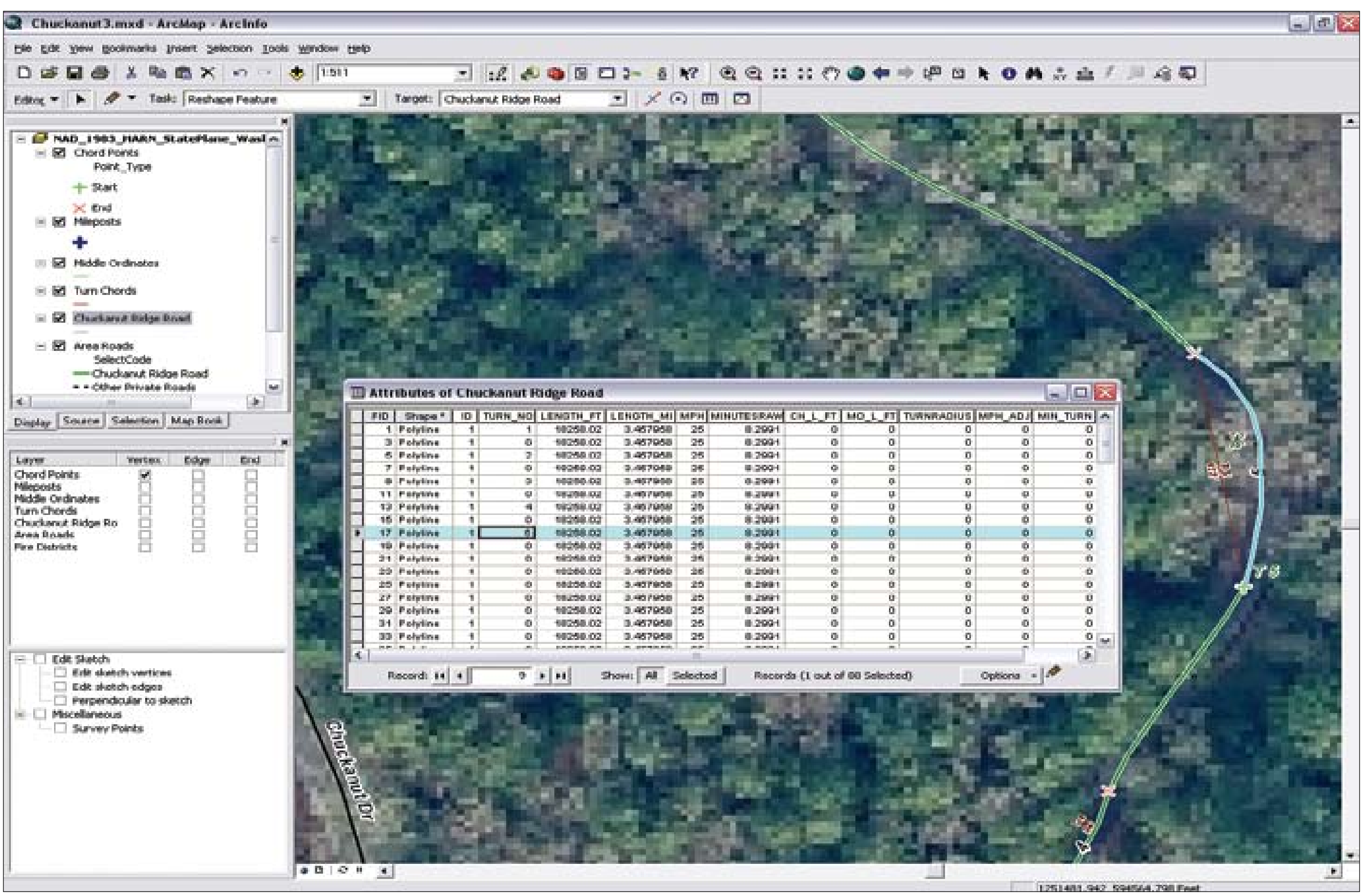
4. Once all the Middle Ordinates have been sequentially built, save the project.

5. Number the Middle Ordinates to match each associated turn using the Field Calculator. Calculate the Middle Ordinate lengths using Calculate Geometry (the same procedure used for the Turn Chord table). Use CR MP 0.5 1:1,500 to zoom in, turn the image back on, and inspect the map. Be sure that all vectors are properly numbered. Save the edits and the map. This might be a good point to stop and take a break.

Task 4: Splitting Lines and Separating Curves

Now it's time to split the Chuckanut Ridge Road into curves and straight segments using the Turn Chord endpoints to locate each split point. When performed manually, this task is quite rigorous. If we could intersect all chords with the road, this would be an easy task. However, using the Chord Points and a special VBScript, the road can be split into curves and straight-line segments. See the accompanying article, "Road Repairs: Splitting Polylines with Visual Basic Scripting," for detailed information on how this procedure is accomplished.

1. Navigate back to Bookmark CR MP 0.0 1:500 once more. Make Chuckanut Ridge Road the Target layer and the only selectable layer and change the Task to Modify Feature. Change the snapping layer back to Chord Points vertex (or alternately, Turn Chords end). Start editing again and reset the Snap-



Number curve segments to match the Turn numbers by selecting a turn segment and entering its number in the Chuckanut Ridge Road attribute table in the TURN_NO field.

ping tolerance to 50 map units.

2. To begin, use the Edit tool to select the Chuckanut Ridge Road, which is one segment. Next, change to the Split Tool on the Editor Toolbar. Move the cursor to the endpoint of Turn Chord 1 and watch the cursor snap to the vertex.

3. Left-click once to split the line. Reselect the uphill (longest) portion of the road and grab the Split Tool again. Break the road at the start of T2. Continue this process in an uphill progression. This makes fixing numbering errors easier. When finished splitting the road, save these edits.

4. The next step is numbering the curve segments to match the Turn numbers. This is a manual process. Open the Chuckanut Ridge Road attribute table. On the map, select the turn segment for Turn 1 and enter 1 in the highlighted record in the TURN_NO field. Proceed to select and number turns from Turn 1 through Turn 47 and do not miss any curves.

5. When finished, sort data by [TURN_NO] and verify curves 1 through 47. Now, use Calculate Geometry to recalculate the length of all segments in both U.S. Feet and U.S. Miles. As an additional activity, recalculate raw travel times [MINUTESRAW] for all segments. Save the edits, end the edit session, and save the map.

Task 5: Joining Chord and Middle Ordinate Lengths and Calculating Turn Radii

Before calculating the radius of each turn, the Turn Chords and Middle Ordinates tables must be joined to the Chuckanut Ridge Road segments. Then the CH_L_FT and MO_L_FT fields in the Chuckanut Ridge Road table will be populated with values.

1. Open tables for Chuckanut Ridge Road, Turn Chords, and Middle Ordinates and adjust the size of each so all are visible.

2. Right-click on the Chuckanut Ridge Road layer, choose Joins and Relates > Join and use TURN_NO as the field in this layer to base the join on, choose Turn Chords as the table to join to this layer and Turn_No as the field in the table to base the join on, and click on the radio button to keep all records.

3. Now calculate the length of all Turn Chords in the Chuckanut Ridge Road table. Use the Field Calculator to populate the Chuckanut_Ridge_Road.CH_L_FT field with the values from Chord1.Length_Ft. Then remove the join by choosing Joins and Relates > Remove Joins.

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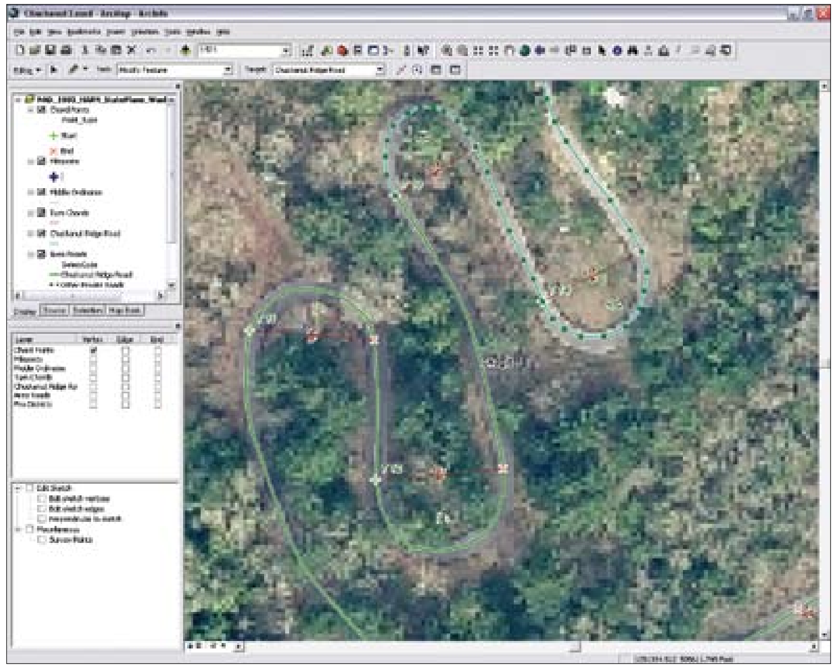

Select Ridge Road, change to the Split Tool, click on the end point of the Turn Chord, and left-click once to split the line. Reselect the next uphill portion of the road, grab the Split Tool, and repeat the process.

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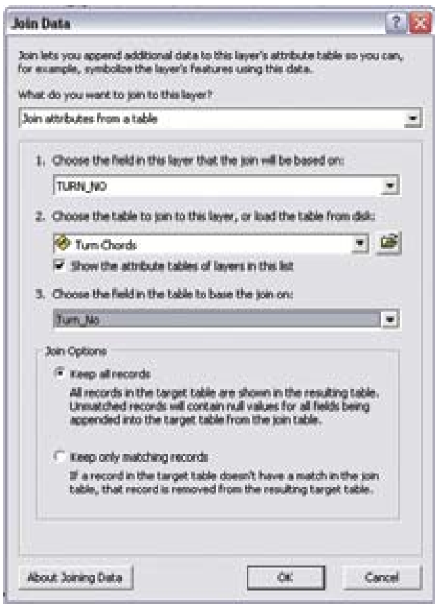
4. Next, join the Chuckanut Ridge Road table to the Middle Ordinates table. Right-click on the Chuckanut Ridge Road layer, choose Joins and Relates > Join and use TURN_NO as the field in this layer to base the join on, choose Middle Ordinates as the table to join to this layer, choose Turn_No as the field in the table to join on, and click on the radio button to keep all records.



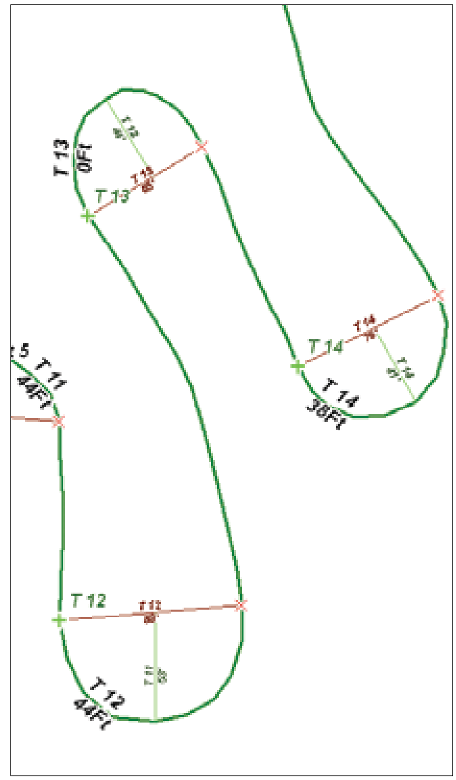
Join the Chuckanut Ridge Road attribute table with the Turn Chords table using the Turn_No field.

5. Right-click on MO_L_FT and use the Field Calculator to populate the MO_L_FT field using values from MidOrd1.Length_Ft.

6. Now the radii of all 47 turns can be calculated. In the Chuckanut Ridge Road table, select all turns by attribute using the formula ([TURN_NO] > 0).

7. Right-click on TURNRADIUS and open the Field Calculator. Type (([CH_L_Ft]^2) / (8 * [MO_L_Ft])) + ([MO_L_Ft] /2) in the formula box. This is the algebraic form of the radius curve formula. Check to verify that all selected records calculate properly. Values will range from just under 25 feet to over 200 feet.

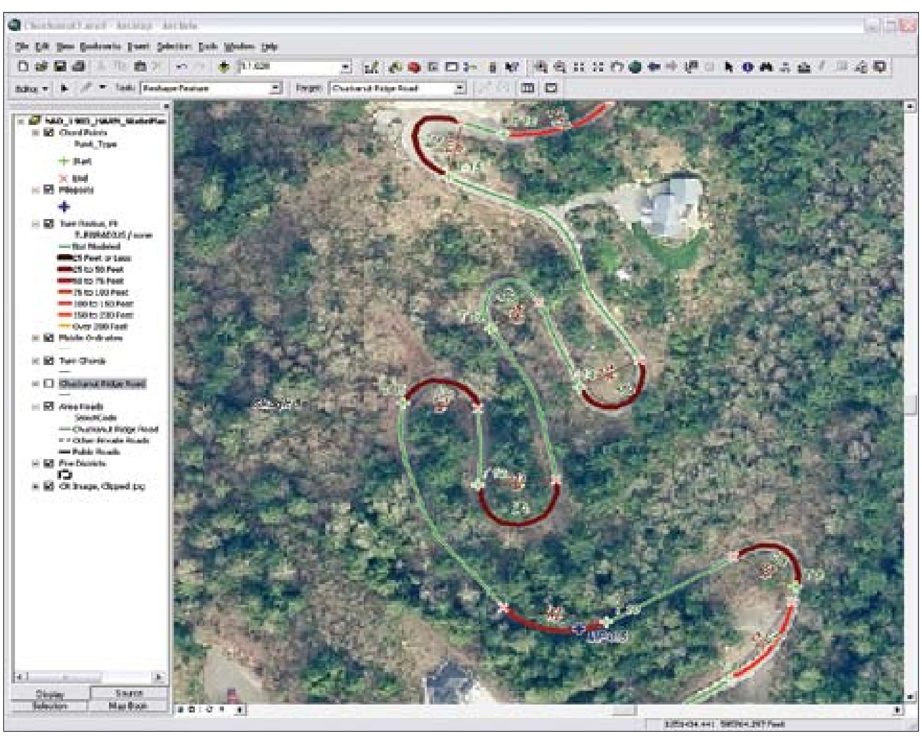
8. To label and study these turns, open the Properties dialog box for Chuckanut Ridge Road and select the Labels tab. Click the Expression button and type "T "& [TURN_NO] &VBNewLine & Round([TURNRADIUS],0) &"Ft" in the Expression box. Change the font to Arial 14 point and apply a halo. Click OK twice to apply the labels and make sure the Label Features box is checked. Inspect them to verify each turn number and radius. Turn the background image on and navigate back to CR MP 0.5 1:1,500.



Use an expression to label the radius of the turns.

9. To apply a thematic legend to these curves based on the turn radius, navigate to \Chuckanut \SHPFiles\WASP83NFH and load Turn Radius, Ft.lyr. Turn off the Chuckanut Ridge Road layer and check the turns. This Turn Radius, Ft.lyr uses the edited road file and applies a color legend that shows the tightest turns with thick red lines.

10. Inspect the map using the extent obtained with the MP 0.5 bookmark. Notice how all the switchback turns at approximately MP 0.7 have similar radii. This road was actually built by loggers nearly 100 years ago. Zoom out to the extent of bookmark CR All 1:15,000 to see the final product. Turn off any labels not needed at this scale. Save the map once more.



Applying Turn Radius, Ft.lyr thematically maps turns and shows the tightest turns with thick red lines.

Acknowledgments

Special thanks to Skagit County GIS for sharing its excellent imagery and terrain data and to the Chuckanut Ridge Homeowners Association and Skagit Fire District 5 for the opportunity to develop and test this model. The author thanks the staff and students at Bellingham Technical College for their help in testing and refining this workflow and to ESRI Canada Limited's Vancouver office for the chance to present this exercise to a sample audience.

Road Repairs

Splitting polylines with visual basic scripting

By Mike Price, Entrada/San Juan, Inc.

Before working this exercise, you should complete "Under Construction: Building and Calculating Turn Radii," which starts on page 50 of this issue of *ArcUser,* so you will understand how to calculate turn radii.

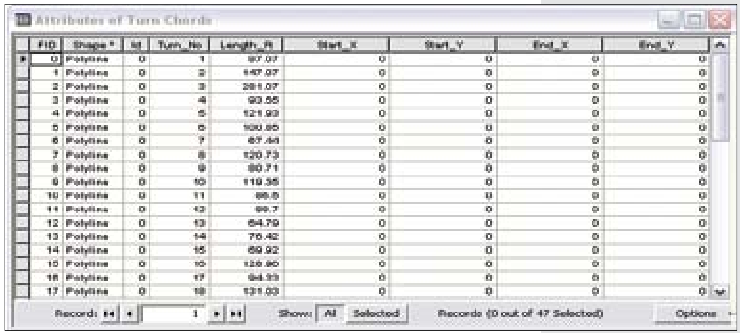
What You Will Need

- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- Sample data (splittinglines.zip) for this exercise from *ArcUser Online*

"Under Construction: Building and Calculating Turn Radii" showed how to calculate turns or curve radii for a steep, winding road. The tutorial used predefined tangent points to create turn chords and to split a road centerline. This exercise will reinforce the turn chord construction technique taught in that article and teach endpoint modeling. It uses a Visual Basic (VB) script that splits all constructed curves in just one run.

This tutorial includes five tasks:

Task 1: After creating turn chords, add fields to store coordinates of start and endpoints.
Task 2: Calculate coordinates of start and endpoints.
Task 3: Load all endpoints as event themes.
Task 4: Run the Visual Basic script to the split road centerline at turn chord endpoints.
Task 5: Assign turn numbers and join turn chord and middle ordinate lengths, then calculate turn radii.



Attributes of Turn Chords

FID	Shape *	Id	Turn_No	Length_ft	Start_X	Start_Y	End_X	End_Y
0	Polyline	0	1	97.07	0	0	0	0
1	Polyline	0	2	147.07	0	0	0	0
2	Polyline	0	3	281.07	0	0	0	0
3	Polyline	0	4	93.55	0	0	0	0
4	Polyline	0	5	121.93	0	0	0	0
5	Polyline	0	6	100.85	0	0	0	0
6	Polyline	0	7	67.44	0	0	0	0
7	Polyline	0	8	120.73	0	0	0	0
8	Polyline	0	9	80.71	0	0	0	0
9	Polyline	0	10	119.35	0	0	0	0
10	Polyline	0	11	86.6	0	0	0	0
11	Polyline	0	12	89.7	0	0	0	0
12	Polyline	0	13	64.79	0	0	0	0
13	Polyline	0	14	76.42	0	0	0	0
14	Polyline	0	15	69.92	0	0	0	0
15	Polyline	0	16	128.86	0	0	0	0
16	Polyline	0	17	64.33	0	0	0	0
17	Polyline	0	18	131.03	0	0	0	0

Record: 1 Show: All Selected Records (0 out of 47 Selected) Options

Create four new fields to store X and Y coordinates for both endpoints.

Getting Started

Download the splittinglines.zip training set from *ArcUser Online*. Extract the data into a project folder and preview it in ArcCatalog. This exercise uses the original road centerline and constructs turn chords and middle ordinates. Hint: When building chords from scratch, be sure to snap to road centerline vertices.

To begin, start ArcMap and open \Chuckanut2\Chuckanut2.mxd. Navigate to \Chuckanut2\SHPFiles\WASP83NFH and add the Turn Chords layer. Open and inspect its table. We will use chord endpoint coordinates to create our splitting points.

Task 1: Add Endpoint Coordinate Fields

First, create four new fields to store X and Y coordinates for both endpoints. These points will be stored in Washington State Plane North American Datum of 1983 (NAD 83) High Accuracy Reference Network (HARN) North in U.S. Feet.

1. Open the Turn Chords table and review its structure.
2. Open Options and select Add Field. Name the field Start_X, set its Type to Double, and set its precision to 14 and its scale to 4. Because this point must be on or very near the target line, the extra precision should help.
3. Add three more fields named Start_Y, End_X, and End_Y. Use the same data type, precision, and scale for all fields.

Task 2: Calculate and Copy Endpoint Coordinates

How to calculate the endpoint coordinates.

1. Begin by right-clicking on the Start_X field on its table header and select Calculate Geometry. Set Property to X Coordinate of Line Start. Use the data frame's coordinate system and set units to Feet U.S. [ft]. Click OK to calculate coordinates.
2. Continue to calculate coordinates for Start_Y, End_X, and End_Y using the same procedure. Select the correct property for each field (e.g., End_X for the End_X field), and if the wrong property is selected, just recalculate the field.
3. Navigate to the select \Chuckanut2\SHPFiles\WASP83NFH and copy Chord1.dbf to the clipboard. Navigate to \Chuckanut2\DBFFiles and paste Chord1.dbf in this folder. Right-click on the file and rename it Chord1_XY.dbf.
4. Add Chord1_XY.dbf back to the ArcMap document and switch to the table of contents (TOC) Source tab. Save the project.

Task 3: Load Endpoints as Event Themes

1. In the Source tab, open and inspect Chords1_XY. Right-click on this table in the TOC and choose Display XY Data. Enter X_Start for the XField and Y_Start for the YField to define the Event Theme. Import the coordinate system from Chords1.shp. Rename this layer StartPoints.
2. Right-click on Chords1_XY again, and again choose Display XY Data. Enter X_End for the XField and Y_End for the Yfield. Import the coordinate system from Chords1.shp. Rename this layer EndPoints.
3. Carefully inspect the points to verify that they are very close to the actual endpoints of each chord. Zoom to Bookmark CR MP 0.0 1:3,000. Save the project.

Task 4: Load and Run the Line Splitting Script

A Visual Basic script that uses points to split line segments will be used to split the Chuckanut Ridge Road centerline. The script and supporting information are available in the \Chuckanut2\Utility\ folder.

1. It is important to remove Turn Chords from the project so the only polyline theme is Chuckanut Ridge Road.
2. In the ArcMap standard menu, choose Tools > Macros > select Visual Basic Editor to open an empty VB scripting window.
3. After the VB Editor opens in its own window, locate the Project window and notice the Normal and Project selections. Selecting Normal will store changes for all maps accessed on this computer. Selecting Project will store changes only for this map document. For this model, select and expand Project.
4. In the VB Editor standard menu, choose the File > Import File. Navigate to \Chuckanut2\Utility, locate SplitLinesAtPoints.bas, and click Open.
5. Expand the Modules folder; double-click

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the SplitLinesAtPoints module to view the VB code. No changes are required to this code. Close VB Window. Save the ArcMap document now to save this script in this project.

6. To run the script in ArcMap, verify that the polyline target (Chuckanut Ridge Road) and the splitting points (StartPoints and Endpoints) are in the TOC. Zoom to Bookmark CR All 1:12,000.
7. Choose Tools > Editor toolbar to load the Editor toolbar, and choose Editor > Start Editing from the drop-down menu. Select the \Chuckanut2\SHPFiles\WASP83NFH\ folder as the folder to edit data from.
8. Make both StartPoints and Endpoints the only selectable layers. Use Zoom Out and the Selection tool or use the table to select all 47 points.
9. In the Tools Menu, choose Macros > Macros > Select SplitLinesAtPoints and click Run. Review the summary windows to see how many points were used to split the road and how many splits occurred. This will actually split the road twice, using both Event Theme sets. Save the edits and the project.

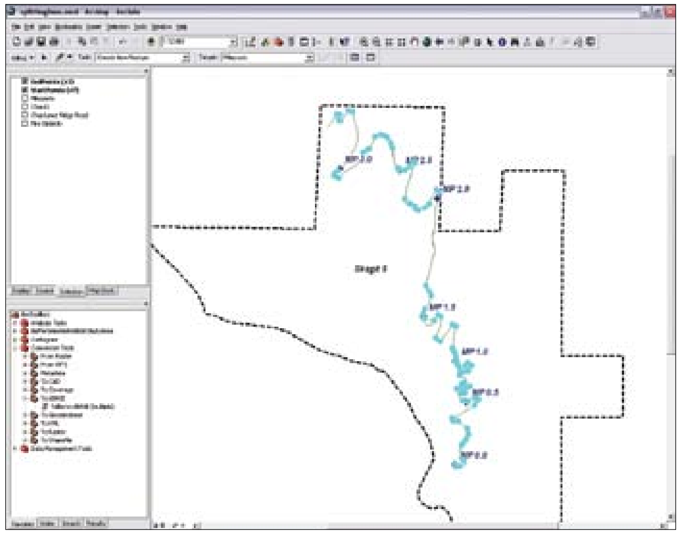
Task 5: Assign Turn Numbers

Reload the Turn Chords layer and add the Middle Ordinate layer and make Chuckanut Ridge Road the only selectable layer. Use CR MP 0.01:3,000 to zoom to the south end of the road.

Use the Turn Chord layer as a guide to select the first turn segment. Either open an editing session to manually assign turn numbers or use the Field Calculator to populate the Turn_No field. Notice that ArcMap labels the segment as the number is assigned. Continue assigning numbers to all 47 turns. Although these turns do not have to be numbered sequentially, it does help keep turn numbers straight.

Finish the Project

When finished assigning numbers, open the attribute table and sort the turn numbers in ascending order. After assigning turn numbers, to reinforce an important point from the original tutorial, join the lengths of the Turn Chord and Middle Ordinate to each road segment. Next, calculate the radius of each turn and thematically map each using the color ramp used in the original exercise. Save the finished project.



After making the event themes, StartPoints and EndPoints, the only selectable themes, select all points and run the SplitLinesAtPoints script.

Summary

This exercise is an extension of "Under Construction: Building and Calculating Turn Radii" in this issue. It teaches how to derive endpoints for polyline segments and how to use the points to split one or more polylines into smaller segments. This workflow has many uses beyond transportation engineering.

Acknowledgments

The author thanks ESRI's Technical Support team for helping develop and deploy this method. An enhancement request has been submitted for this task and several related tasks that also surfaced while developing this exercise.

Investigating the Changing Earth

Using historical and current imagery from TerraLook

By Joseph Kerski, ESRI Education Manager

Examining how the landscape changes over time is one of the most useful applications of remote sensing in education. Whether that change is caused by the seasons, natural disasters, or human impacts, using remotely sensed imagery can bring home the point that the Earth is a dynamic planet—one of the critical themes in geography education and arguably an important theme in Earth science, life science, environmental studies, and other disciplines.

It has been challenging to easily obtain and georeference a sequence of aerial photographs or satellite images of the same area of the Earth's surface to detect changes. A relatively new resource, TerraLook (terralook.cr.usgs.gov), has made that process much easier. This U.S. Geological Survey Web site provides recent and historical satellite data as georeferenced JPEG images at no charge. The source data is the global land datasets using Landsat data (from the 1970s and circa 1990 and 2000) and the full Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) archive (2000 to 2008). Note that TerraLook does not make the full multiband ASTER datasets available for free—just the georeferenced images derived from them. Still, it is a tremendous resource for both research and instruction. The datasets are provided as simulated natural color images. TerraLook's goal is to serve data users who need images of the Earth but may not have technical remote-sensing expertise or software.

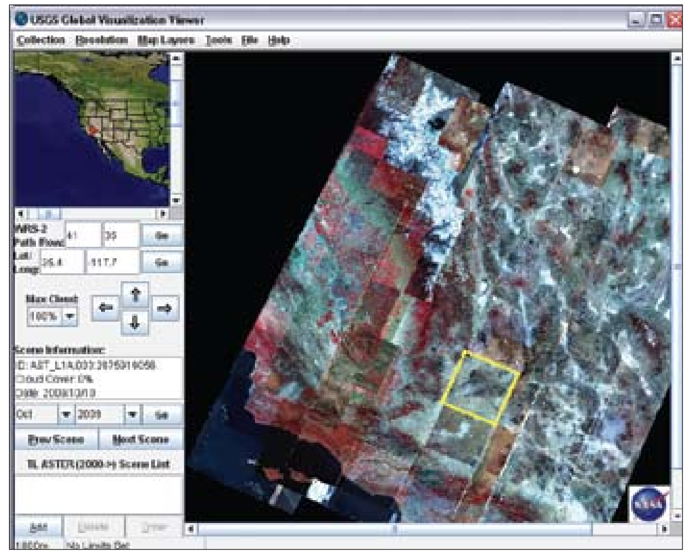
TerraLook collections are one to hundreds of satellite images from a single region or many regions of the globe chosen by users of the site from the Landsat or ASTER images available. Images are selected using the Global Visualization Viewer (GloVis) available from the TerraLook site. With GloVis, specific image types can be selected for particular areas of the planet via a mapping interface. When an order is ready, an e-mail message is sent to the user that contains instructions and a link for downloading the ZIP file that contains the images and metadata.

One of the best things about TerraLook is that image collections of many countries and some areas have already been created and can be downloaded directly from the site. The ZIP files for these image collections can be very large but can still be downloaded with a broadband connection.

Images from TerraLook can be easily brought into ArcMap or the free TerraLook software available at terralook.sourceforge.net. The images come with a vector file containing the satellite "footprints" of all the images downloaded. The site is being translated into several languages.

Because images from the different years have varying pixel sizes, comparing the images in the TerraLook software is an excellent starting point for a discussion about scale and spatial resolution. The Landsat Multispectral scanner (MSS) images from the 1970s on the site are composed of pixels that are 57 square meters in size, while Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images on the site have pixels that are 28.5 square meters. The ASTER pixels are 15 square meters. The areal coverage also varies: the ASTER images, at 60 by 60 kilometers, cover about one-ninth the area of Landsat images, which are 185 by 170 kilometers. Consequently, urban areas, reservoirs, and other features will look different not only because images were taken at different times but also because of the resolution of the images.

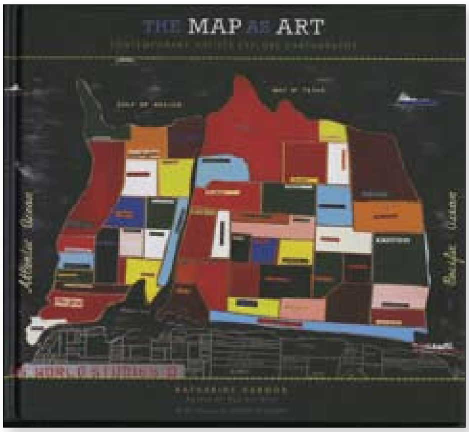
What sorts of changes will you be able to detect from the TerraLook collections? You should be able to see evidence of large-scale changes such as those from the eruption of Mount St. Helens, the drying up of Lake Chad and the Aral Sea, evidence of fires at Yellowstone National Park and elsewhere, and changes to topography caused by flooding rivers and glacial retreat. I also encourage you to look for less dramatic but equally interesting changes. Some of these changes could be seasonal, such as vegetation response to South Asia's monsoons, the advance of the growing season each spring, and the differences in the seasonal cycle between the Northern and Southern hemispheres. Other changes reflect human impact on the planet, from urban sprawl to the construction of dams and airports to the expansion and contraction of agriculture depending on local conditions and population pressures.



Images are selected using the Global Visualization Viewer (GloVis) available from the TerraLook site.

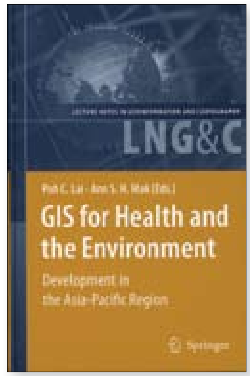
From TerraLook, I downloaded a series of images for Phoenix, Arizona, and loaded four of them into ArcMap. In the resulting layout (shown in the figure above), it is possible to detect changes in this rapidly urbanizing environment. Approximately 5 percent of Maricopa County, the county that includes Phoenix, is under the control of five Indian Nations. Land belonging to three of these nations—the Gila River Reservation to the south and the Salt River Pima-Maricopa and Fort McDowell Mohave-Apache communities to the northeast—border the urbanized area. In 1975, the Salt River boundary was clearly evident on the satellite image. By 2000, negotiations between the Salt River Nation and the State of Arizona had resulted in a freeway and adjacent development. By 2004, this had reduced the extent of irrigated fields in that area. Freeway development is controversial in Phoenix and elsewhere. You can have your students investigate the ongoing South Mountain Freeway debate, using these images as a starting point. I encourage you to make use of these images from TerraLook in your own research and instruction.

gis Bookshelf



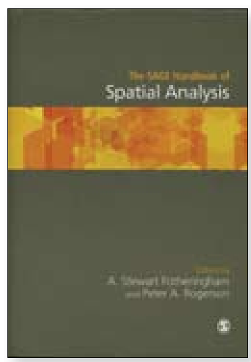
The Map As Art: Contemporary Artists Explore Cartography
By Katharine Harmon

That there is art in mapmaking is well known and appreciated. *The Map As Art: Contemporary Artists Explore Cartography* takes the opposite tack by examining the maps in art. Salvador Dali, Marcel Duchamp, and Jasper Johns are just a few of the artists who have used maps in their works. This book illustrates the varied and surprising ways maps have been incorporated into works of art. In paintings and drawings in every sort of medium—from cotton stretched on a frame to the skin on a man's back—as well as in models and installations, this book displays the inventive, novel, and amazing ways cartography has been used in artistic expression. Photographs of these works are accompanied by essays written by Gayle Clemans. Princeton Architectural Press, 2009, 256 pp., ISBN-13: 978-1568987620



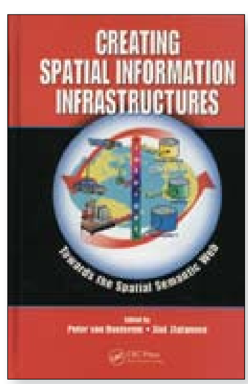
GIS for Health and the Environment: Development in the Asia-Pacific Region *(Lecture Notes in Geoinformation and Cartography series)*
Edited by Poh C. Lai and Ann S. H. Mak

Concerns over the spread of both swine and avian influenzas have underlined the importance of GIS-based epidemiological studies. In addition to these studies, this book also addresses GIS applications for modeling human and environmental factors associated with disease, disease modeling, and public health monitoring and response. This book is a compilation of papers from the International Conference in GIS and Health held in 2006. Its intended audience includes geospatial experts, practicing epidemiologists, medical doctors, environmentalists, and public health physicians concerned with the impact of environmental exposures on the health of populations. Springer, 2007, 310 pp., ISBN-13: 978-3540713173



The SAGE Handbook of Spatial Analysis
Edited by A. Stewart Fotheringham and Peter A. Rogerson

Spatial analysis requires specialized statistical and mathematical methods. *The SAGE Handbook of Spatial Analysis* provides a broad overview of the spatial analytic techniques currently available as they are applied in a range of disciplines. It gives both a retrospective and prospective look at spatial analysis that is both comprehensive and authoritative. This book describes the main areas of spatial analysis, key areas of debate in the field, examples of applications, and problems in spatial analysis. Graduate students and researchers working with spatial data, as well as professionals who perform spatial analysis, will find this book invaluable. Sage Publications Ltd., 2009, 528 pp., ISBN-13: 978-1412910828

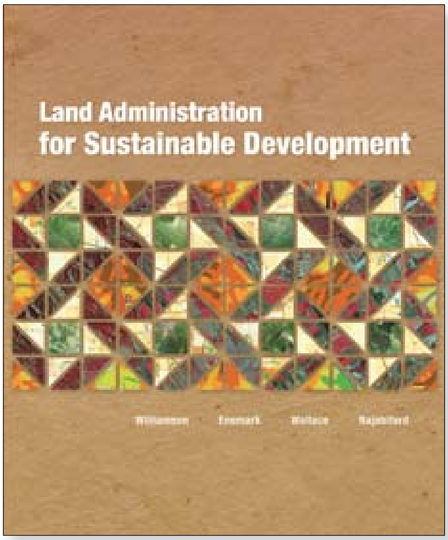


Creating Spatial Information Infrastructures: Towards the Spatial Semantic Web
Edited by Peter van Oosterom and Sisi Zlatanova

The tremendous increase in the amount of spatial data accessed via the Internet has demonstrated the need for better methods of organizing and retrieving it. While spatial data infrastructure (SDI) initiatives, such as Infrastructure for Spatial Information in Europe (INSPIRE), are developing data standards that promote the use of spatial data, the problem of locating suitable datasets remains. Thus, spatial data represents a special case of the more general problem of developing a semantic Web that would enable and refine the ability to locate information on the Web. *Creating Spatial Information Infrastructures: Towards the Spatial Semantic Web* reviews recent SDI initiatives and addresses social aspects, such as legal and organizational issues, that impede access to spatial data as well as technical solutions for making metadata available via registry services and the use of formal semantics. CRC, 2008, 216 pp., ISBN-13: 978-1420070682

Looking for Sustainable Patterns

Implementing a modern land administration system



Land Administration for Sustainable Development is a timely book that examines the development of modern land administration theories and practices. It describes, from a global perspective, new and innovative policies, systems, and technologies that have been applied to the rapidly evolving concept of land administration.

Local concerns and considerations mandate different approaches to land administration systems (LAS). Although many approaches have been implemented throughout the world, their common goal is addressing land management strategies that ensure social equality, economic growth, and environmental protection. This book examines some of these systems at various levels of development and provides insights into the strengths and weaknesses of each.

While recognizing that all countries or jurisdictions have their own needs, the book highlights the underlying features of land administration necessary for the success of any LAS. These fundamental elements include the implementation of a GIS-enabled spatial data infrastructure (SDI), the "key to the spatial enablement of modern land administration."

This book is written for anyone looking for a comprehensive overview of modern LAS strategies: LAS professionals, politicians, senior government officials, students, land administrators, and land-related professionals.

The book's four authors bring a broad base of experience. Ian Williamson is a professor of surveying and land information at the University of Melbourne, Australia, who has authored or coauthored numerous articles on cadastre, GIS, land administration, and spatial data infrastructures. Stig Enemark is a professor of land management at Aalborg University, Denmark; president and an honorary member of the International Federation of Surveyors; and past president and an honorary member of the Danish Association of Chartered Surveyors. Land policy lawyer Jude Wallace is a senior research fellow at the Center for Spatial Data Infrastructures and Land Administration at the University of Melbourne. Abbas Rajabifard, a professional land surveyor and chartered engineer, is an associate professor of spatial data infrastructure and director of the Center for Spatial Data Infrastructures and Land Administration at the University of Melbourne and is president of the Global Spatial Data Infrastructure Association.

Land Administration for Sustainable Development (ISBN-13: 9781589480414, 512 pp.) is available at online retailers worldwide, at www.esri.com/esripress, or by calling 1-800-447-9778.

Exploring the Spatial Dimensions of Public Health

Survey helps improve access to clean water in sub-Saharan Africa

By Susan Harp, ESRI Writer

Clean drinking water is hard to find in Mayange, Rwanda. That's why a group of university students and two professors from the University of Redlands (U of R) in California traveled there. Using the GIS technology and GPS equipment they brought along, they mapped the area's water sources and collected water use information. Their survey will help improve access to clean drinking water in Mayange and in similar communities across sub-Saharan Africa.

The maps will provide local sustainable development programs with accurate information on where people get their water. For example, the data can be used to identify areas where water sources are contaminated and support decisions about improving water quality such as how to protect an open pit water source or where to dig a new water source. Ultimately, this field collection and mapping model may be used for mapping other water networks in Rwanda and parts of Africa and contribute to the implementation of sustainable practices in impoverished nations.

"Anything that we can do to improve water quality is going to have a major impact on the population," said Max Baber, Ph.D., associate professor in the master of science in Geographic Information Science program at the U of R. Baber and Katherine Noble-Goodman, a visiting lecturer in environmental studies at the university, led U of R undergraduate environmental studies students to the rural Mayange sector in 2008 and 2009.

Professor Max Baber enters information into a computer as local residents in Mayange sector, Rwanda, add their knowledge of local features to paper maps of the area.

In the bigger picture, the project contributes to the Millennium Development Goals (MDG)—an ambitious plan that pledges to eliminate extreme poverty worldwide by 2015. Representatives from 192 United Nations (UN) member states signed on to the MDG commitment to reduce poverty by improving health, education, agriculture, and infrastructure. Access to clean drinking water plays an important part in supporting these goals. MDG aims to reduce by half the proportion of people without sustainable access to safe drinking water.

Some progress has been made in advancing MDG goals, but in sub-Saharan Africa, improvements have advanced more slowly than in other parts of the world. As a result, the Millennium Villages Project (MVP) was established to create a successful model in Africa for alleviating poverty using a set of integrated, community-driven activities.

> "Anything that we can do to improve water quality is going to have a major impact on the population."
>
> Max Baber
> Ph.D., associate professor in GIS

Mayange, with a sector population of 25,000, is one of 80 communities spread across 10 African countries that are participating in MVP. Located in one of the poorest regions in Rwanda, the area is almost completely deforested and receives 800 millimeters (about 31.5 inches) of intermittent annual rainfall. As in many other rural African areas, Mayange villagers spend hours each day retrieving water their families need to survive. Often the water source is contaminated. This can cause health problems. The time-consuming process of obtaining water also diverts efforts from activities crucial to sustainable development such as education and farming. "Clean, reliable sources of water for drinking, cooking, and other basic human needs are a necessary condition for the elimination of poverty and the success of sustainable development," said Noble-Goodman. In Rwanda, more than 25 percent of the population lacks access to clean water.

Students mapping the location of a shallow well in Mayange sector, Rwanda, consult with local residents to gather additional information about well usage.

Using GPS equipment and ArcGIS, the teams spent a total of 15 days in May 2008 and 2009 in the field mapping and classifying water access points such as wells, lakes, and cisterns. With help from local village leaders and guides and personnel from Rwanda National University and MVP, the students built a database of water sources by collecting GPS points in the field and classifying each site as a shallow well, open pit, lake, deep borehole, water tap, or cistern.

The team also collected survey data by talking with individuals who arrived at the sites to fill their water cans. The survey provided information on water use, household location and size, distance to the water source, and the seasonal availability of water. The survey's purpose was to help MVP participants prioritize areas in most need of improving the quality and quantity of water sources. "One goal of MVP is to have water within one kilometer of every household. This is very ambitious and will take a while," said Molly Moore, a U of R student who participated in the project.

The data is being held by Didace Kayiranga, MVP science coordinator in Mayange. "It gives us tools for planning and to evaluate our indicators such as distance from a household to a clean water source," said Kayiranga. "This indicator cannot be easily measured without overlaying the different household and water point layers."

The GIS fieldwork gave students hands-on experience to learn how GIS technology can support projects that study the relationship between humans and the environment. "And for a few days in May," said Noble-Goodman, "students had the opportunity to help improve the community's access to clean, safe drinking water."

"Working in an extremely rural, undeveloped area also provided new lessons" said Baber. "Students learned about the nature of uncertainty in collecting GIS data, such as mapping a community that does not have an address system and issues that can cause deterioration of the accuracy of GPS readings."

U of R faculty and students continue to edit and revise the project data in graduate GIS classroom studies as a way to explore the spatial dimensions of public health issues. They are running analyses and creating spatial models to predict relative likelihood of productivity for new borehole well site locations. In the most commonly employed model, inputs are derived from household density (as analog for population density so that proximity to population concentrations is incorporated in the model) and relative terrain situation (valley or ridge, for relative proximity to groundwater).

For this project, U of R collaborated with Loma Linda University School of Public Health (www.llu.edu/llu/sph/), National University of Rwanda Geographic Information Systems and Remote Sensing Centre (www.cgisnur.org), and the Millennium Villages Project (www.millenniumvillages.org). Grant money was provided by the Southern California Metropolitan Water District through a program that challenges students to develop water-conserving technology in impoverished nations.

To learn more about the students' mapping project, contact Max Baber at max_baber@spatial.redlands.edu.

Hardware Used

- Garmin 60CSx
- Dell Precision M4300 portable workstation

Software Used

- ArcGIS

Basemap Data Sources

- SRTM 90 m digital elevation data
- QuickBird images
- Millennium Villages Project
- National University of Rwanda GIS and Remote Sensing Centre
- Rwanda government (administrative boundaries)

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

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ESRI continues expanding course offerings to make instructor-led training available to users where and when they need it.

GIS-Based Project Supports College's Commitment to Climate Neutrality

In 2007, Green Mountain College (GMC) became the first institution of higher education in Vermont to sign the American College & University Presidents Climate Commitment (ACUPCC). This is an agreement by colleges and universities to take practical measures to limit greenhouse gas emissions associated with campus operations and promote research and educational efforts toward climate neutrality. In response, students at GMC used GIS to create a baseline inventory of faculty and staff commuting trends to limit the college's carbon footprint.

GMC is a small liberal arts college in rural Vermont. Its environmental mission provides the underpinnings for its general education program and led to two ambitious goals: to substantially lower greenhouse gas emissions and purchase offsets for emissions that cannot be reduced. To reach these goals, GMC integrated this initiative into the curriculum through interdisciplinary departmental collaboration and service-learning projects.

After assessing the results of a greenhouse gas inventory in 2007, the college outlined short-, mid-, and long-term goals for emissions reduction with the goal of achieving climate neutrality by 2011. While installing a combined heat and power (CHP) biomass facility in 2009 would reduce most of the college's emissions, improving the GMC fleet's fuel efficiency and creating a transportation demand management system will reduce emissions related to transportation, the second largest contributor to GMC's carbon footprint.

GMC faculty and staff who live in western Vermont and eastern New York commute to work. To achieve climate neutrality, GMC must consider how far each faculty and staff member travels, vehicle efficiency, and frequency of commute. In spring 2009, two students created a preliminary baseline inventory of faculty and staff commuting trends using GIS.

Each spring, students in the *Introduction to GIS* course must participate in a service-learning project working with a community partner to help address an issue of concern. Jane Day and Kyla Jaquish, students in the spring course, selected the commuter inventory for their semester project.

Day and Jaquish used a database that included 141 of the 224 faculty and staff who work at the institution. Primary data provided home addresses but did not include the type of vehicle for each commuter. After identifying the geographic coordinates for each commuter address, the students created a commuter address shapefile.

They performed a cost-distance analysis along the roads in Vermont and New York, assuming the cost of traveling through each grid cell of 30-meter digital elevation model (DEM) data actually was 30 meters. This provided a more accurate representation of distance traveled than a straight-line-distance analysis. Using a spatial join, the address shapefile was used to extract from the cost-distance grid the distance traveled for each commuter. These distance values were exported to Microsoft Excel and used to characterize commuter trends and provide a baseline estimate for total gasoline consumption, total miles driven, total carbon emitted by employee vehicles, and employee distance from the college.

These values indicate faculty and staff drive a combined total of 3,136 miles each day, and assuming an average fuel efficiency of 23 mpg/highway, this daily commute consumes approximately 174 gallons of gas, creating approximately 1.5 metric tons of CO_2 per day. Assuming each employee commutes three days per week, the total annual carbon emissions from commuting are approximately 234 metric tons. However, because 50 percent of these commuters live within five miles of campus, there is strong potential for developing an efficient carpooling infrastructure.

These assumptions and estimates will be further refined as addresses become available for remaining employees and when data summarizing actual car models and frequency of daily commutes is collected. The baseline inventory can be expanded as more data becomes available. Through this project, students used GIS to address a community issue and helped the campus move toward its goal of climate neutrality.

Remapping the World's Population

Visualizing data using cartograms

By Benjamin D. Henning, John Pritchard,
Mark Ramsden, and Danny Dorling
Department of Geography, the University of Sheffield

Explore Data Using a Free Tool

The Cartogram Geoprocessing tool, available from ArcScripts, can be used for creating cartograms in ArcMap. A cartogram is a transformation of a map that uses some variable instead of land area to expand or contract the area of the original polygons based on an attribute value. Cartograms are often used for displaying population data. The Cartogram Geoprocessing tool was developed by ESRI staff member Tom Gross. It uses the density-equalizing methodology developed by Mark Newman and Michael Gastner at the University of Michigan. A new version of the Cartogram Geoprocessing tool released in May 2009 allows the tool to be used in a Python script. This new version uses the currently selected data and honors definition queries. Visit **www.esri.com/arcscripts** and search on the keyword *cartogram*.

The Worldmapper project has successfully produced a series of maps to visualize data concerning a range of issues facing the modern world based on the idea of density-equalizing maps. With this approach, ArcGIS 9.3 plays a crucial role as an interface to convert suitable raster datasets and produce updated cartograms. The data is converted using ArcMap's ArcToolbox, while the cartograms were calculated using a geoprocessing tool available from ESRI's ArcScripts site. The final visualization was performed in ArcMap. This article introduces and evaluates further new mapping approaches that move depictions beyond their simple descriptive form. It gives an insight into these new developments, focusing on subnational-level data that has, until now, been neglected.

Worldmapper and Its World Population Cartogram

The world population cartogram demonstrates the first attempt to include subnational density data. In the first stage of the Worldmapper project, a wide range of maps depicting various human dimensions of the world have been published on the project's Web site (http://www.worldmapper.org). Since the publication of the first new world population cartogram in 2006, nearly 600 maps have been produced, going far beyond the depiction of the world's population and covering topics such as education, poverty, and pollution. The Worldmapper cartograms show the data for 200 territories, thus making this new view on the world to some extent an arbitrary view: territorial borders are artificial and are subject to change. Furthermore, the assignment of territories in Worldmapper is arbitrary as different thoughts on these territories might exist. Therefore, the world population cartogram was taken as an example to test different ways to calculate these cartograms beyond the territorial borders. *[Additional information on the calculations used in and the design of existing Worldmapper cartograms is given in "Worldmapper: The World as You've Never Seen It Before," by Danny Dorling, Anna Barford, and Mark Newman, published in the September 2006 issue of* IEEE Transactions on Visualization and Computer Graphics.*]*

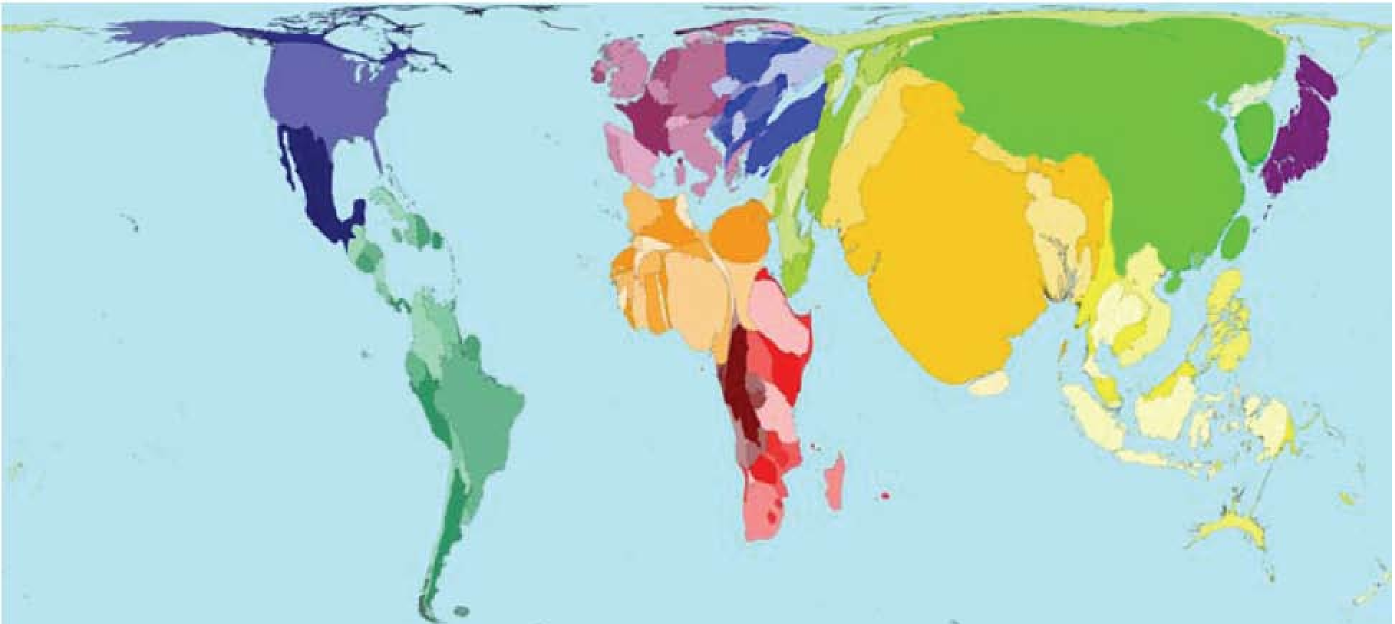

Figure 1: Worldmapper Population Cartogram

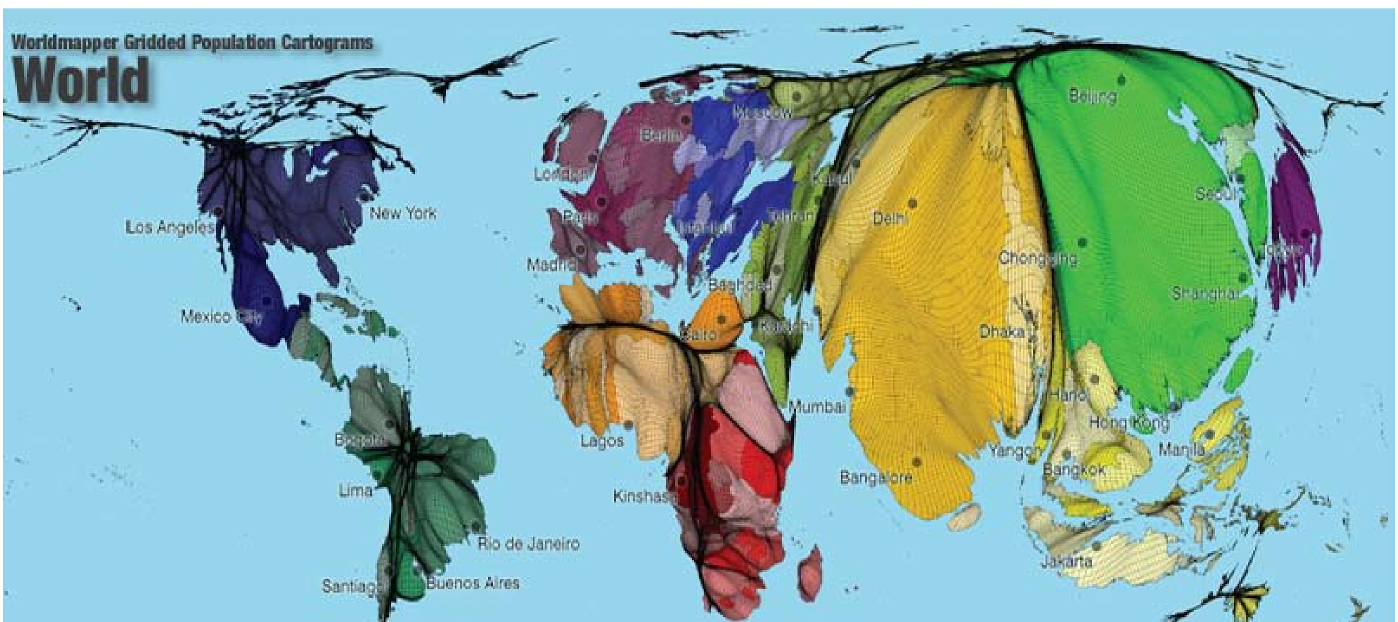

Figure 2: Grid-Based World Population Cartogram (2000)

Data and Cartogram Calculation

Data used in this work was derived from the Socioeconomic Data and Applications Center (SEDAC) of Columbia University, New York. The Gridded Population of the World (GPW) database contains the distribution of the world's population on a gridded base (sedac.ciesin.columbia.edu/gpw/), including population data and estimates from 1990 to 2015. This data is available in resolutions of up to 2.5 arc minutes, leading to a population grid of 8,640 x 3,432 pixels. Data from the year 2000 has been used to make results comparable to the original Worldmapper population cartogram.

This raster format data was imported to ArcGIS, converted to polygons, and combined with further metadata (e.g., country labels) to match grid cells for further visualization tasks. The cartogram script uses a 4,096 x 2,048 pixel-sized lattice for its map results.

The cartogram itself was calculated using the Cartogram Geoprocessing tool created by Tom Gross of ESRI and available from the ESRI ArcScripts site (www.esri.com/arcscripts). It uses density-equalizing methodology developed by Mark Newman and Michael Gastner at the University of Michigan. Unlike the Worldmapper cartograms that distort an initial projection of the boundaries of the territories, each population grid is treated as a separate part for the calculation, not taking any territorial information of borders into account. Thus each grid cell marks a border so that distinct shapes of countries are intentionally of no interest in the calculation.

Changes in the distortion of the resulting

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Remapping the World's Population

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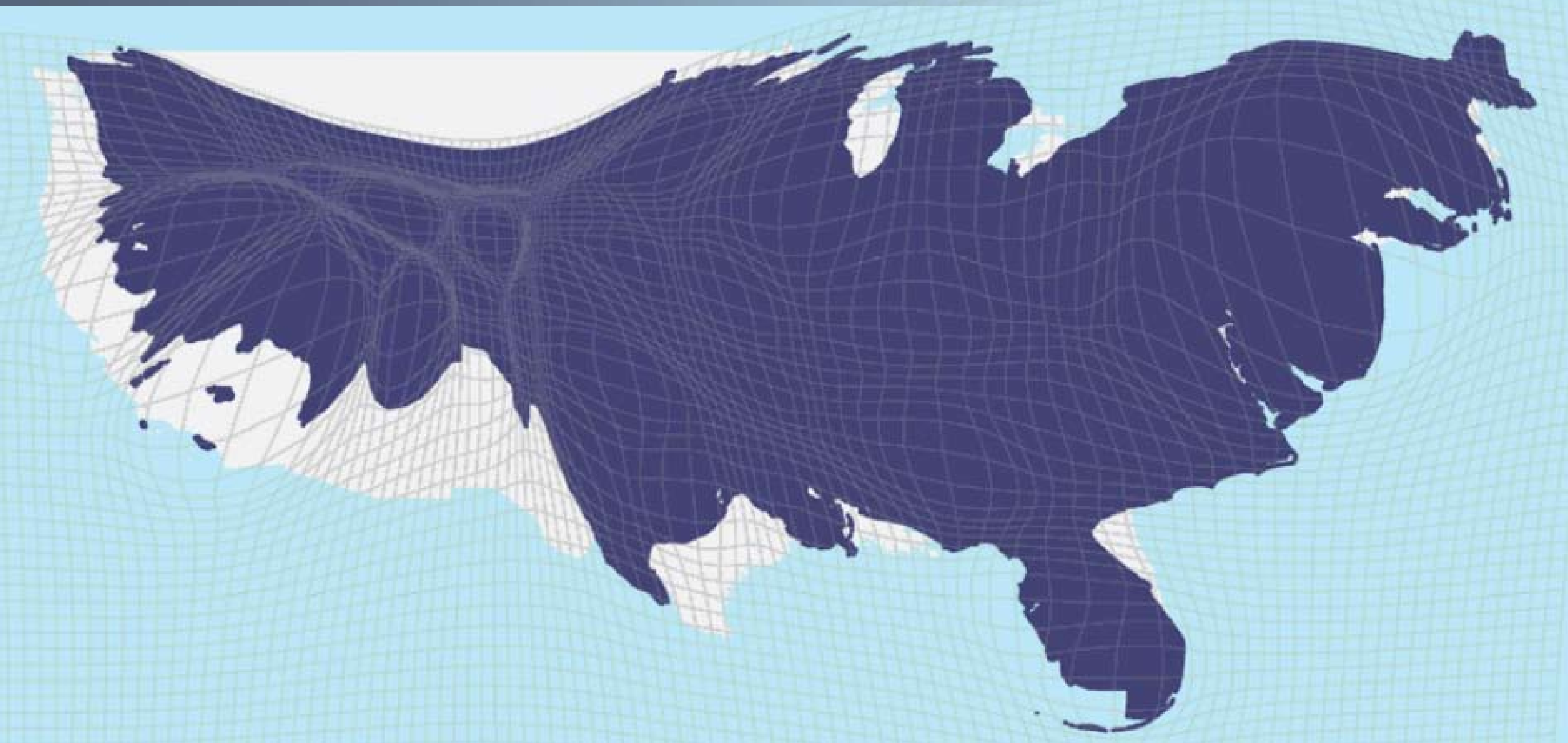
cartogram thus are only possible by adjusting the factor to smooth the original density. In addition, data from the USA has been extracted from the 2.5 arc minutes population grid and is calculated separately in the same way to produce a more detailed view of the resulting grid and its interval variation.

Figure 3: Grid-Based Population Cartogram of the Contiguous United States (2000)



Results

The resulting cartograms require some final visualization steps to adapt them to appear similarly to the original Worldmapper cartograms. The polygons of the calculated world population cartogram are dissolved according to their affiliation to the Worldmapper territories and colored according to the distinctive Worldmapper color scheme. The gridlines in the USA cartogram are preserved to show the degree of distortion within the grid.

A Redrawn World Population Cartogram

Compared to its predecessor (Figure 1), the redrawn World Population Cartogram (Figure 2) shows considerable differences. For example, in China the sparsely populated Himalayan regions can be distinguished from the densely populated eastern coastal regions. Internal variation within the United States and Mexico can also be recognized. Somewhat harder to identify but still evident are north-south differences in Great Britain and west-east differences in Germany. Hence, our goal to take the varying distributions of population on a subnational level and make them visible on a global view has been achieved. However, subnational variation can be difficult to analyze in more detail because the grid cells are eliminated to sustain the view on the global scale. In addition, more distinctive national shapes are far more distorted than in the original cartogram, which for some users might appear odd when interpreting such maps.

Down to Earth: A Population Cartogram of the United States

To counter the loss of familiar national boundary shapes, a separate population cartogram is produced for the contiguous United States (Figure 3) and several other countries. The shape of the cartogram has more detail compared to the shape of the USA on the world population cartogram. This is because more grid cells are used in the calculation of the cartogram and no other polygons (e.g., from the European continent) influence the calculation. The different scale also allows the visualization of each grid cell so that subnational variation can be recognized. An "original" map of the USA with its familiar shape is shaded in underneath the grid to aid interpretation.

This visualization on a different scale is an improvement that goes far beyond the current capabilities of the Worldmapper project by using gridded base data to allow a different view of population distribution not only worldwide but also within separate regions. By using cartogram techniques, a different view on the regional variations of human geography is created, which can hardly be achieved with traditional mapping techniques.

Outlook

The most significant obstacle to the realization of gridded depiction for Worldmapper will be the vast quantity of different topics covered and availability and reliability of data. Reliable gridded social and economic data for the whole world is rarely available and rarely of such good quality as the population data. The estimation of missing national data for some topics has already been a serious matter in the existing Worldmapper cartograms. Such estimations will not meet the demands of gridded datasets, so new ways of data estimation are needed.

Current approaches to estimate data commonly use the GPW data, and these have the potential to be adapted to Worldmapper's requirements. Revised gridded cartograms offer great potential to enhance the variety of Worldmapper's visualization capabilities. A different view of the "real" location of the depicted topic can present a better understanding of human action and human patterns on the globe.

However, distortions associated with the gridded method are a disadvantage and undermine the purpose of Newman and Gastner's algorithm to preserve the familiar shapes of countries. The potential of the gridded approach and the desire to preserve the familiar shapes must therefore be carefully balanced. Nevertheless, much potential lies in adding more user interactivity and detail to Worldmapper. Grid-based cartograms have the advantage of allowing a user to zoom in to view national and regional details, within a global context. As one of the authors, Danny Dorling, has commented, "Our maps could be made more interactive, certainly, and there are probably many other features that could be added."

GIS technology is a key tool to make this happen. A GIS environment not only facilitates data conversion and calculation of cartograms but also allows different geographic scales to be brought together under one map. An easy transfer to popular digital globes can thus be realized, allowing viewers to identify the regional dimension of a subject. Separate regional editions of gridded population cartograms can be generated to visualize the regional variation of population distribution.

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