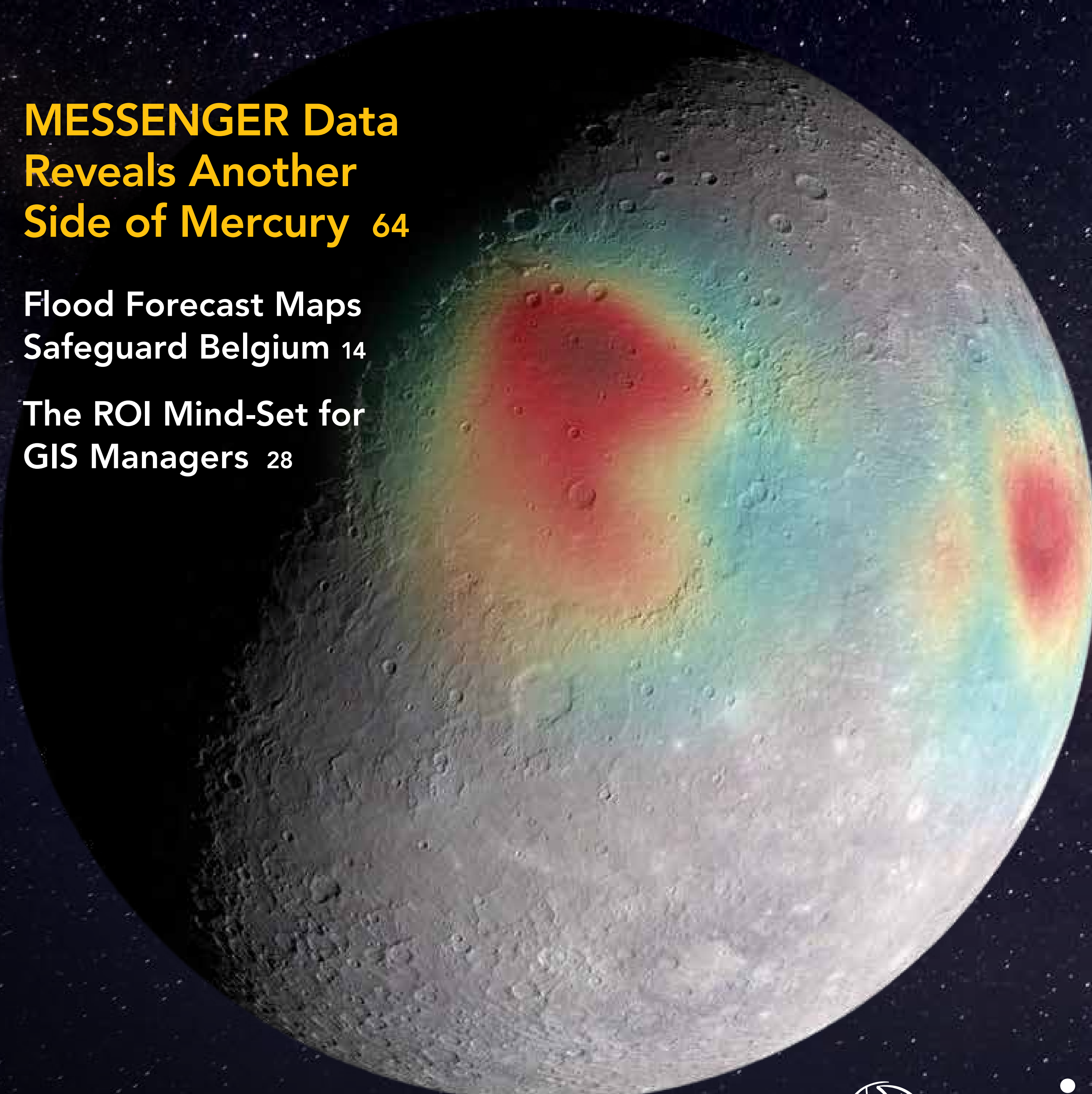
Winter 2016

ArcUser

The Magazine for Esri Software Users



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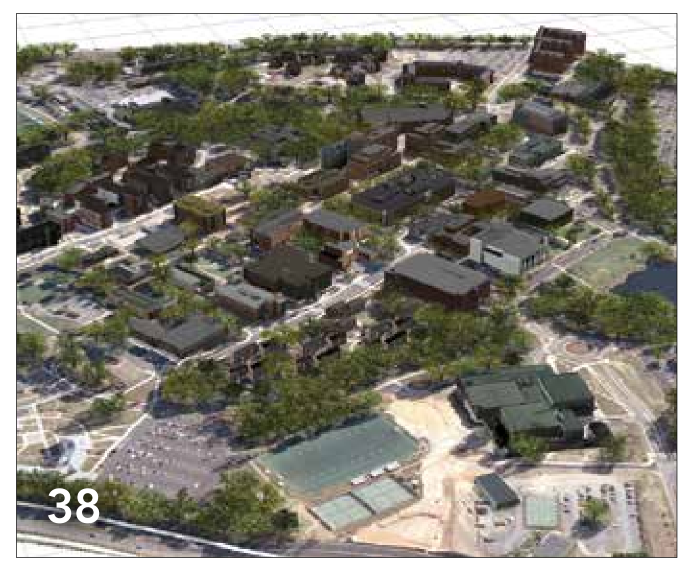

Special Section: 3D GIS

Openly Supporting Successful Systems

In December, Esri announced that its recently patented Limited Error Raster Compression (LERC) technology would be freely shared with the geospatial community through open source licensing.

LERC is an algorithm that provides fast lossless and controlled lossy compression of image and raster data. In combination with NASA's Meta Raster Format (MRF) for optimizing web access to rasters, LERC will significantly improve access to imagery and raster data stored in the cloud.

Sharing LERC is just a recent example of Esri's open approach to developing technology. Esri's developers have participated on GitHub for years. They maintain open APIs that enable others to integrate Esri technology with other solutions.

For many years, Esri has supported open data standards through its participation in the Open Geospatial Consortium, Inc. (OGC), and the International Organization for Standardization (ISO). This commitment to open data has extended to products, such as ArcGIS Open Data, which have been developed specifically to enhance data exchange. With ArcGIS Open Data, organizations have a simple method for sharing data with others.

By embracing multiple pathways to interoperability, Esri technology can harness the power of geography to developing areas of IT such as big data and the use of real-time data to turn massive data collections into actionable information. This approach supports the thousands of successful Esri software users in the vital work they do with GIS.

Monica Pratt

Monica Pratt
ArcUser Editor

editor's page

ArcUser

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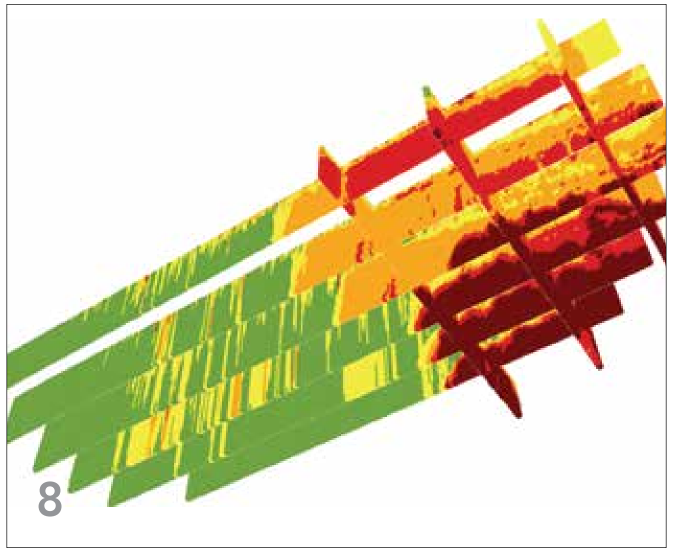

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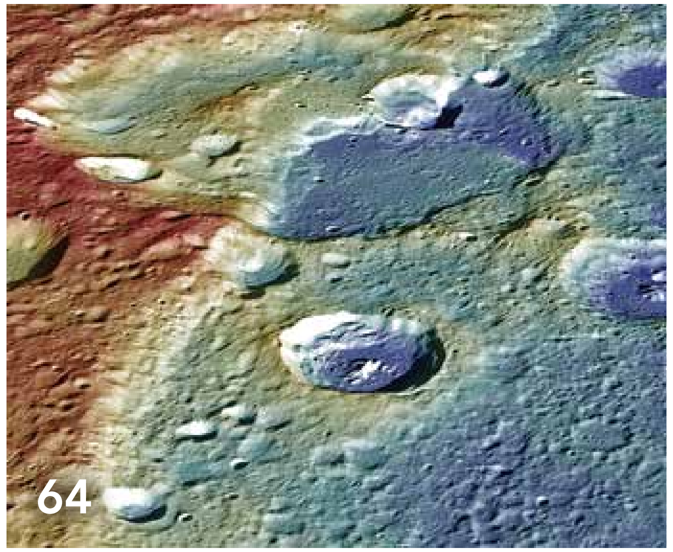

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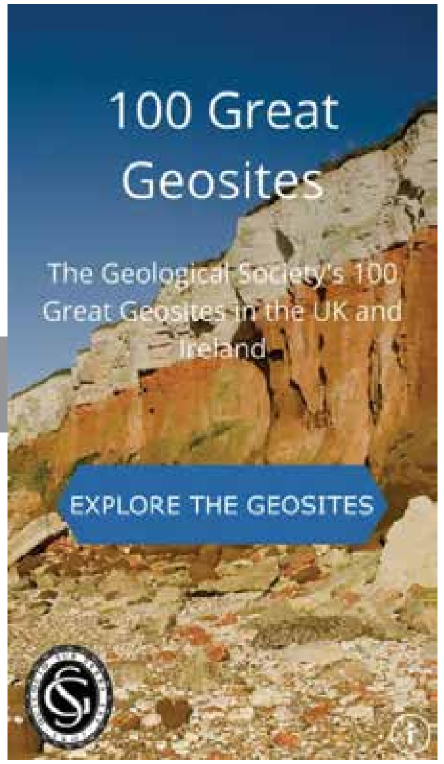
Departments

ArcGIS Online Release Features

AppStudio for ArcGIS



One of the highlights of the November update to ArcGIS Online is the release of AppStudio for ArcGIS, a groundbreaking tool that lets you build one app and deploy it across multiple form factors and platforms—Mac, iOS, Android, Windows, and Linux—and publish them to all app stores.

Now that AppStudio for ArcGIS is no longer in beta, it is included with ArcGIS Online subscriptions. AppStudio for ArcGIS Basic lets users turn maps into beautiful, consumer-friendly mobile apps that run on all devices—no developer skills required. Upgrading to AppStudio for ArcGIS Standard provides additional benefits: the ability to distribute apps within the enterprise and extend apps built using AppStudio's configurable templates; it also allows developers to create custom apps. For more information on AppStudio, visit esri.com/appstudio.

Other apps that come with an ArcGIS Online subscription have new capabilities. ArcGIS Online has a full suite of configurable apps that do most of the work for you once you have created a web map. The ArcGIS Online help topic "Choose a configurable app" will help you identify your purpose and intended audience so you can choose the most suitable configurable app from the many that are available.

Web AppBuilder for ArcGIS has four new widgets: a Batch Attribute editor to simultaneously edit multiple attributes, a Reviewer Dashboard widget to display data quality result statistics as infographic pie and bar charts to summarize data quality issues identified in the GIS data, a Feature Report widget to collect and manage data quality feedback from users, and an Image Measurement widget to perform measurements on image services with mensuration capability. Other enhancements include support for six new URL parameters; automatic saving of app state; and more print, search, editing, and attribute-related improvements.

The immensely popular Collector for ArcGIS app has a new set of data collection templates for creating hosted feature layers. Two new apps, Survey123 for ArcGIS and Workforce for ArcGIS, complement Collector for ArcGIS.

Survey123 for ArcGIS is available in beta. This app allows users to incorporate smart forms into field data collection efforts. Available in the Apple, Google Play, and Windows app stores, this easy-to-use mobile application lets fieldworkers capture data while connected or disconnected. Survey123 for ArcGIS provides a solution for form-centric data collection workflows in ArcGIS. To learn more and get the app, visit survey123.esri.com.

Navigator for ArcGIS improves field workforce reliability by letting them find sites no matter where they are located using voice-guided directions and automatic route recalculation for one or more stops. Workers can access downloadable maps for offline navigation. It supports multiple travel modes and integrates with other ArcGIS apps such as Collector for ArcGIS and apps you develop.

AppStudio for ArcGIS lets you turn maps into beautiful, consumer-friendly mobile apps that run on all devices. The UK Geological Society's 100 Great Geosites app is available as a web, iOS, and Android app.

The Workforce for ArcGIS app, soon to be available in beta, helps field crews work like a team. With Workforce for ArcGIS, users in the field can easily get work assignments and communicate the status of work back to the office, all from one device. The Workforce for ArcGIS mobile app, supported on the iOS platform, seamlessly integrates with all the mobile ArcGIS apps including Navigator for ArcGIS, Collector for ArcGIS, and Survey123 for ArcGIS. Combined with Operations Dashboard for ArcGIS, the suite of apps provides a robust solution for optimizing fieldwork.

Building and updating story maps has also gotten easier. Create and modify maps as well as identify and troubleshoot issues, in the builder mode in Story Map Journal and Story Map Series. Story Map Basic has been updated and now supports search, sharing subscriber content publicly, adding a logo in the header, and configuring color themes. (This update doesn't apply to existing Story Map Basic apps. To take advantage of the new features, users must share their maps again using the updated app).

For ArcGIS Online administrators, the Maps and Apps Gallery app makes it easier for your organization's users to find the configurable apps they want using filter and search capabilities.

The new Minimalist viewer app has a simple user interface—just a map with a scale bar and zoom slider—but it can be configured to show a content panel that presents a legend, map details, or pop-up info.

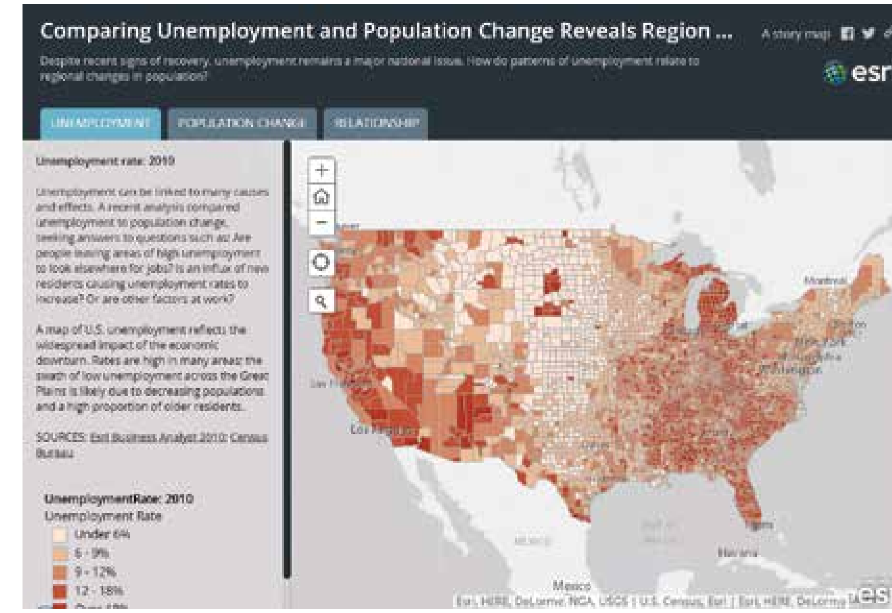
Access to and use of the Basic Viewer app by individuals with disabilities has been improved as part of an ongoing goal by Esri to design and implement accessible GIS products and technologies that align with the objectives of Section 508 of the Rehabilitation Act of 1973, a US federal law.

Other apps that have been enhanced include

- GeoForm, a template that allows users to edit feature data in a form, is no longer part of the Early Adopter Template group and is now fully supported and available in the Esri-featured configurable apps gallery.
- Crowdsource Reporter has been responsively designed for use in browsers on smartphones, tablets, and desktops.
- The Crowdsource Polling app is now available in the Esri Featured Apps section of the gallery.
- A new version of the Elevation Profile app now supports toggling layers, a basemap gallery, sharing to social media, feature search, custom URL parameters, and options for customizing the color scheme.

Several apps have been retired. Instead of using the Legend app, use the Simple Viewer. Use the Public Information app in place of the Twitter app.

This release of ArcGIS Online also includes improvements for administering and managing ArcGIS Online; enhanced security, new visualization capabilities; and updates to World Imagery, World Street Map, and World Topographic Map services. For more details and links to helpful resources go to the ArcGIS Online What's New page at links.esri.com/agolhelp/whatsnew.



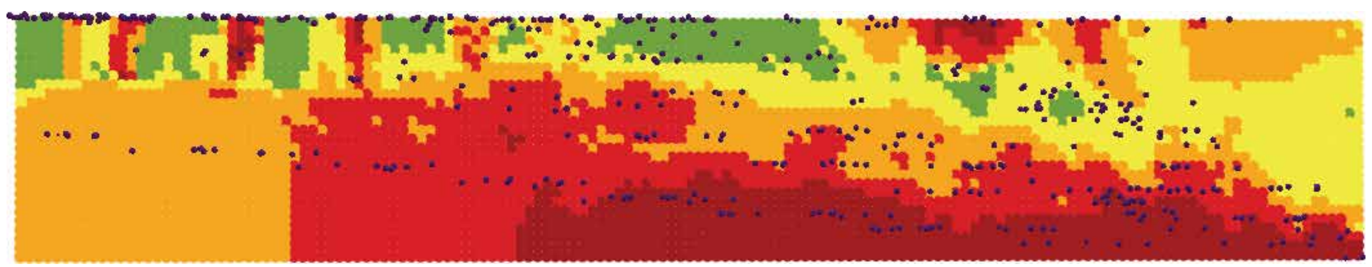
Use the builder mode in Story Map Journal and Story Map Series maps to identify and troubleshoot issues.

The default version of the new Minimalist viewer app has a simple user interface—just a map with a scale bar and zoom slider.

Transforming 3D Data into FENCES AND CURTAINS with Geostatistical Tools

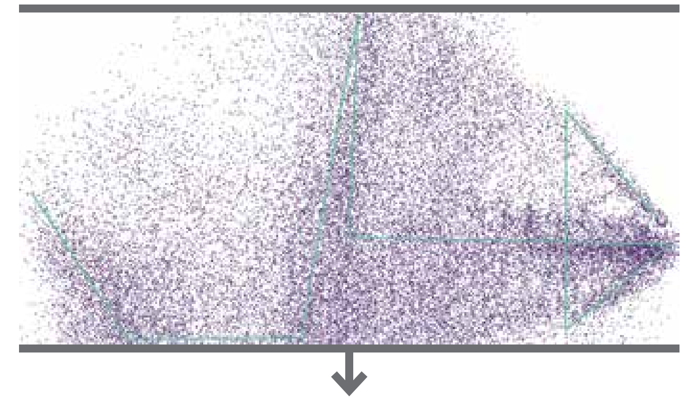
By Witold Fraczek and Bob Gerlt, Esri Prototype Lab

Top view of a slice of points shown in purple, and the resultant fence presented as a colored line in the center of the input points.

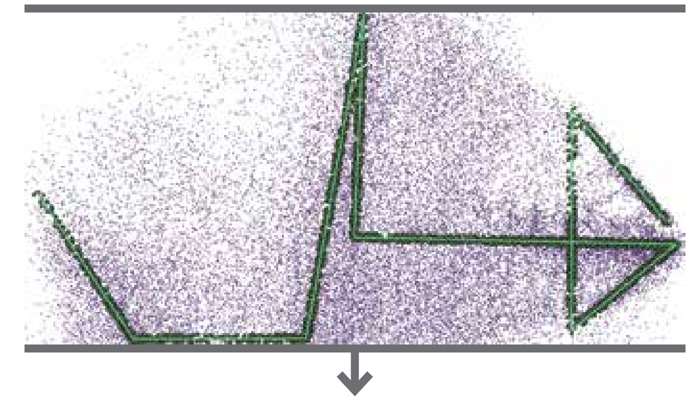


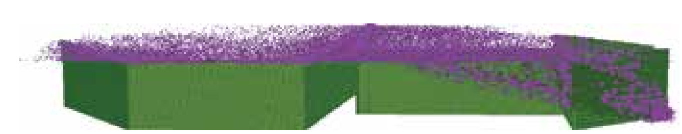
Side view of the input slice points located on one side of the resultant fence. The points are measurements of oil in seawater after an oil spill.

With the points displayed in ArcMap, open the Interactive Fence tool and draw a fence through areas that look interesting.

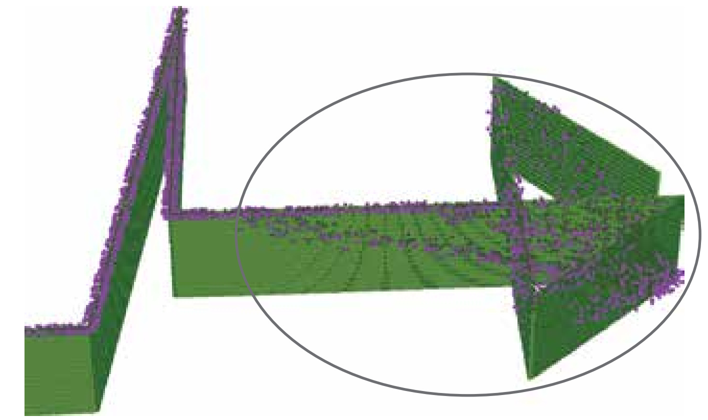


With the Interactive Fence tool, the user can digitize multiple lines, even self-intersecting lines, and set the buffer distance from these lines. All points located within the buffer will be used for geostatistical analysis.





By running the tool, you can inspect the depth variation of points in areas of interest. The points that will be used for the geostatistical interpolation are shown in green.



After running the tool, most of the variance in depth appears to be located on the east side of the sample. To better understand the phenomena, you could concentrate study in the area inside the circle or use fences parallel, rather than perpendicular, to depth.

A new Python toolbox available from ArcGIS Online provides three tools that enable geostatistical analysis of vertical slices from 3D point samples. These tools transform slices, rotating them 90 degrees to a horizontal 2D plane and performing geoanalysis.

For years, ArcGIS users have been able to perform sophisticated geostatistical interpolation of data samples in two dimensions with the ArcGIS Geostatistical Analyst extension. Using this extension, they can take measurement data obtained at selected locations for a phenomenon and create continuous maps.

Natural phenomena—such as the gradient of air temperature, the content of an ore at various geologic strata, or the salinity of the ocean along adjacent vertical transect lines—can be described by 3D data. Studies of atmospheric cross-sections, geologic profiles, and bathymetric transects have become an integral part of GIS. The growing availability of 3D data and the popularity of its use for analysis has created a demand for geostatistical analysis capabilities for 3D data.

GIS is used to analyze not only natural but also man-made phenomena. For example, human impacts on air, earth, and water that can be analyzed in 3D include air pollution and oil spill plumes. Air pollution can migrate into the ground and be moved by groundwater drift. When an oil spill migrates from the bottom of an ocean to its surface, oil can sometimes be dragged by ocean currents. The need for greater insights in such occurrences to increase the understanding of these phenomena was the motivation for creating the 3D Fences Toolbox.

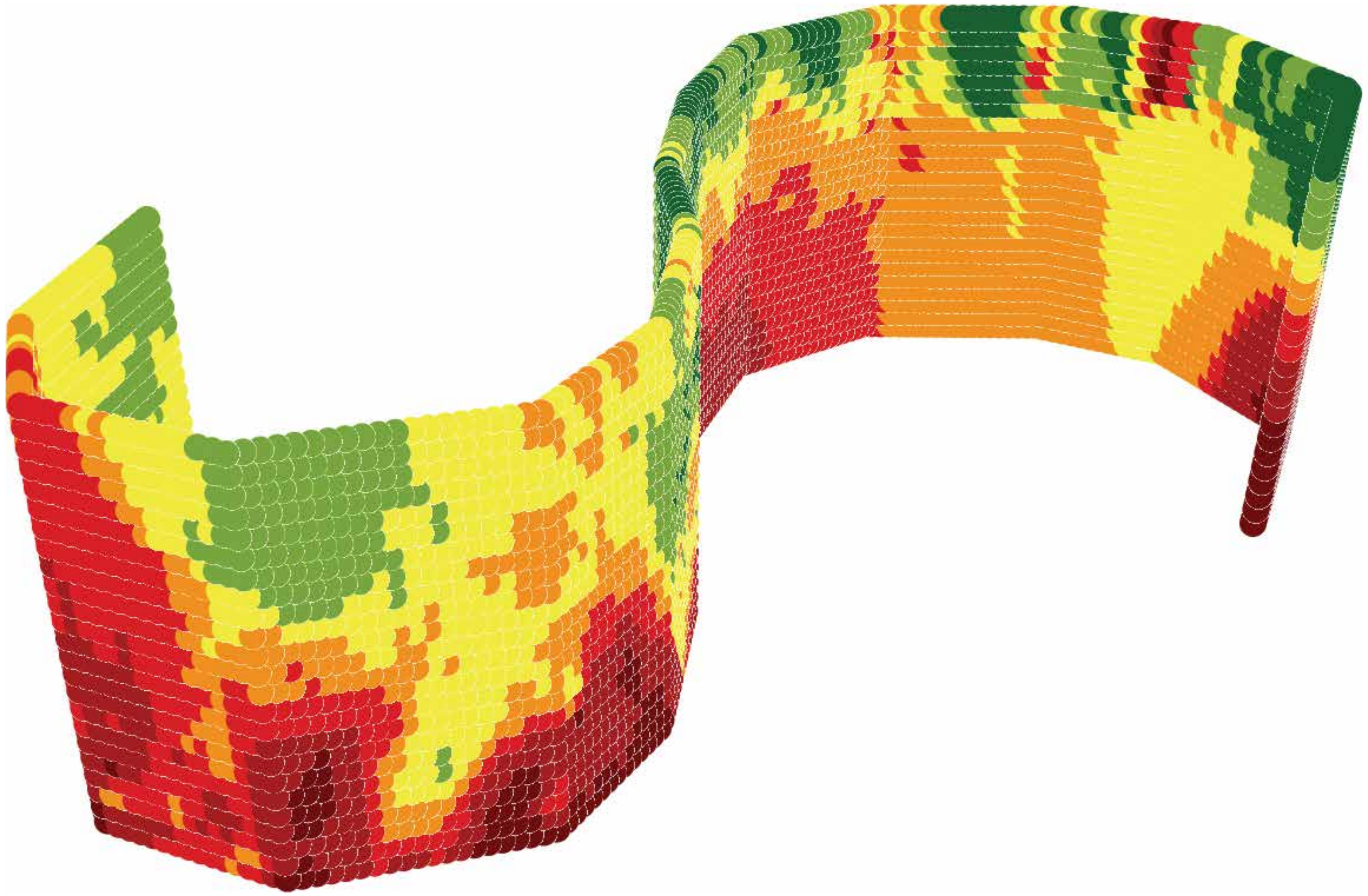
To understand how the tools in the 3D Fences Toolbox work, you must understand two terms: *slice* and *fence*. A slice is a vertical subset of the 3D data analogous to a slice of bread from a loaf. While typically narrow in one dimension, it still is a 3D object.

All the points in a slice are projected or pressed onto a 2D plane. In geology this is called a fence. The equivalent of a fence in the atmospheric sciences is usually referred to as a *curtain*. As an example, a fence can be used to illustrate a cross-section of geologic strata generated from an interpolation of the data coming from a linear array of vertical drillings.

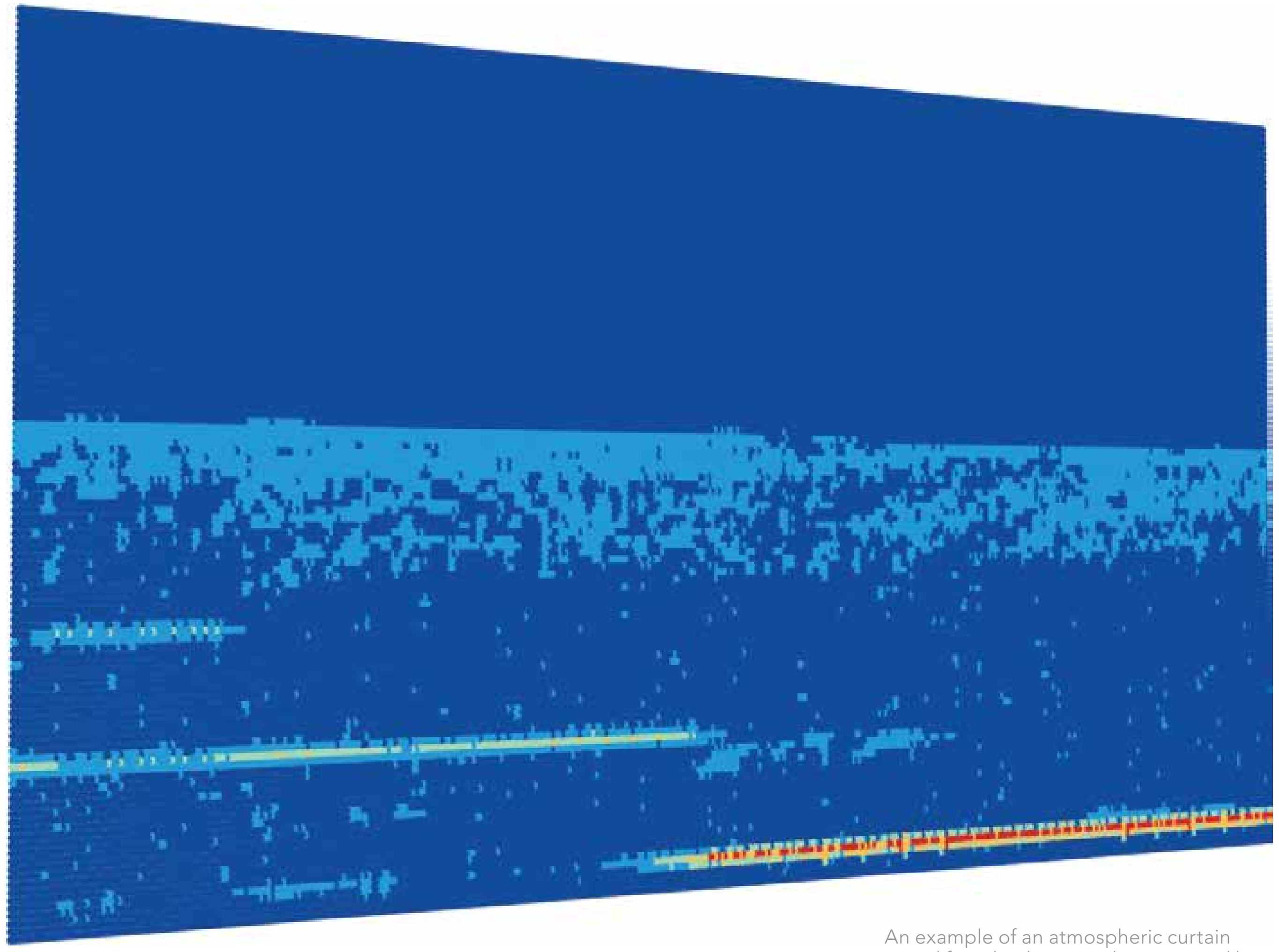
The tools in the 3D Fences Toolbox do not perform 3D interpolation and do not implement geostatistical analysis directly on vertical slices of 3D data. Instead, these tools transform a slice of 3D data containing x-, y-, and z-values that measure the phenomenon by rotating it 90 degrees to a horizontal 2D plane.

Geostatistical interpolation using the Empirical Bayesian Kriging (EBK) is performed on these points in a horizontal 2D plane, which produces either a geostatistical surface of prediction or a map of the Prediction Standard Error. A geostatistical surface of prediction is a continuous map of the concentration or intensity of something, while a map of the Prediction Standard Error is a map of the degree of confidence in the prediction map at each location of the map.

The 3D Fences Toolbox tools enable geostatistical analysis of phenomena such as oil spills. This photo shows oil leaking from a disabled vessel. Photo courtesy of ENTRIX, Inc.



A fence created along a digitized "S" shape.



An example of an atmospheric curtain created from backscatter data acquired by NASA from its Calipso satellite orbiting at 32 kilometers above the earth's surface.

The resultant output from this transformation process is converted to a point dataset where the points represent the interpolated values at the center of each raster cell. The points are then placed back into the original coordinate space as a regular matrix of points resembling a fence. The fence is positioned in the center of the selected points of the initial slice when displayed in ArcScene (a module of the ArcGIS 3D Analyst extension) or in ArcGIS Pro. The raster is converted to a point dataset because ArcGIS does not currently support display of raster data as a vertical plane. In addition, point symbology options provide added flexibility in displaying results.

Any ArcGIS standard or geostatistical point interpolation tool could have been implemented in the 3D Fences Toolbox. However, for the prototype, EBK was chosen because it is the geostatistical method known for its best-fitting default parameters and accurate predictions. Motivated, Python-savvy users can easily change the interpolation method employed by the tools if input data warrants the use of a different method.

The 3D Fences Toolbox consists of three separate tools that support different methods of generating fences. The Parallel Fences tool can generate sets of parallel fences in directions that are related to either longitudes, latitudes, or depths. In other words, the output sets of parallel fences can stretch from north to south, from west to east, or through the *z* dimension. The number of fences in each set is determined by the user. All tools support selection sets to create fences from a subset of sample point features.

The Interactive Fences tool can generate fences based on lines digitized on the map. The user sets the buffer distance from the digitized line, and all points located within the buffer will be used for the geostatistical analysis. The user may digitize multiple lines and even self-intersecting lines with many vertices.

The Feature Based Fences tool creates fences based on existing features in a polyline feature. In this case, the fence shape is determined by the existing feature(s) and extends through the *z* dimension of the selected sample points. For example, this tool might be applied to detect oil leaks above an oil pipeline located on the seafloor.

All tools contain options that enable the user to determine the minimum number of sample points and fence size required to generate a reasonable geostatistical surface. The tools are also time aware. If the sample data contains a date-time field and the option is enabled, a fence will be generated for each time interval if the samples for that interval and location meet the minimum requirements set by the user. The resultant fences representing consecutive time windows are positioned at the same locations to enable better visual analysis; these fences should be displayed as time animations.

To download the 3D Fences Toolbox, go to arcgis.com/home/item.html?id=441cdbc3a5cf4f62bd447f30c61483ff.

The Platform Enables

a More Comprehensive Approach to El Niño

"People the world over are feeling, or will soon feel, the effects of the strongest El Niño event since 1997–98," announced climate scientists at NASA's Jet Propulsion Laboratory in December 2015.

The last El Niño of comparable strength was responsible for ice storms in the northeast; New England, and Canada; tornados in Florida; and widespread flooding and landslides in portions of California that caused 35 counties to be declared federal disaster areas.

A recurring phenomenon, El Niño events happen when sea surface temperatures in the equatorial Pacific Ocean rise, influencing air and moisture movement across the earth and often causing above-average precipitation.

The spring issue of *ArcUser* in 1998 featured an article describing how GIS analysts at Vandenberg Air Force Base in California, used ArcInfo, ArcView GIS, and ArcView 3D Analyst with the HEC RAS hydraulic modeling package to identify which base facilities would be impacted by flooding and landslides and model measures to minimize these impacts. Their analysis not only saved infrastructure but also preserved important habitat.

Organizations dealing with the 2015 El Niño event have many more GIS tools for responding to its effects. These effects of major flooding extend beyond the immediate preservation of people and property to other sectors of the economy, from agriculture to retail.

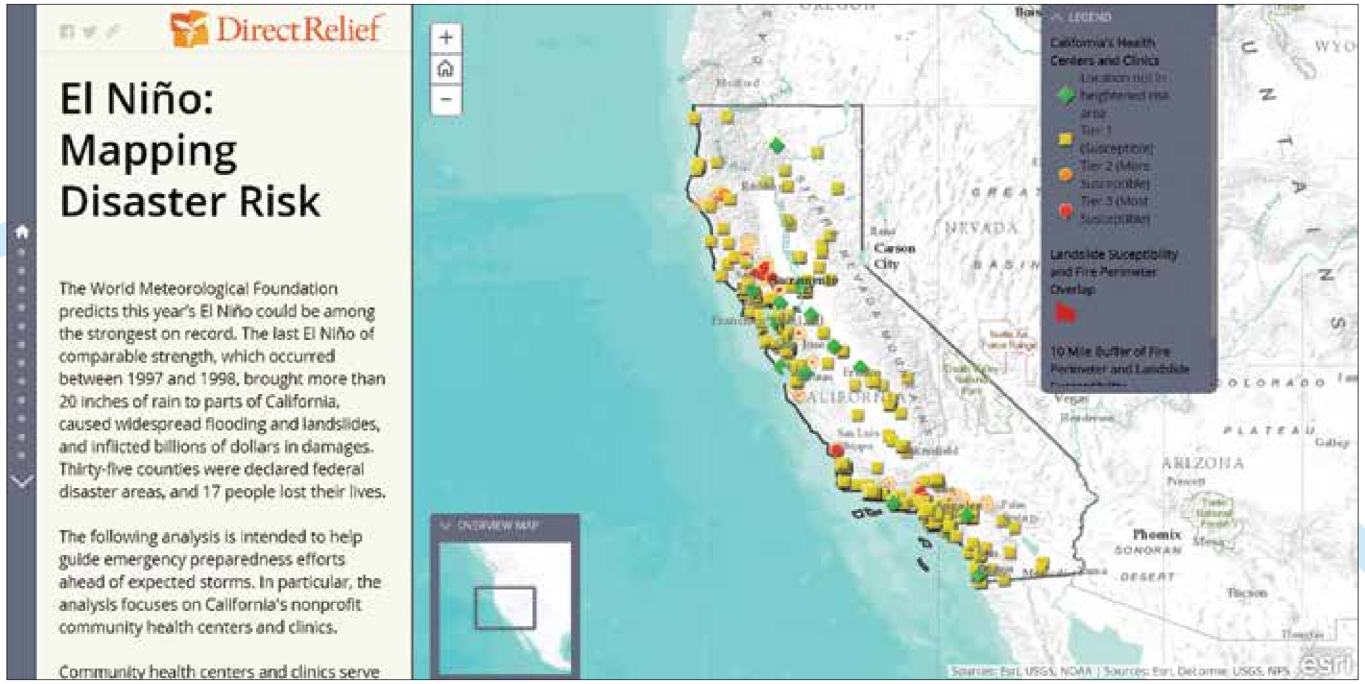
For example, a GIS framework can minimize disruptions to the supply chain by providing a centralized source of accurate information for efficiently coordinating shipments and rerouting them as necessary. With this overview, managers can control changes in response to conditions and track assets. The GIS that is now furnishing the information infrastructure for many organizations so they can address potential disruptions.

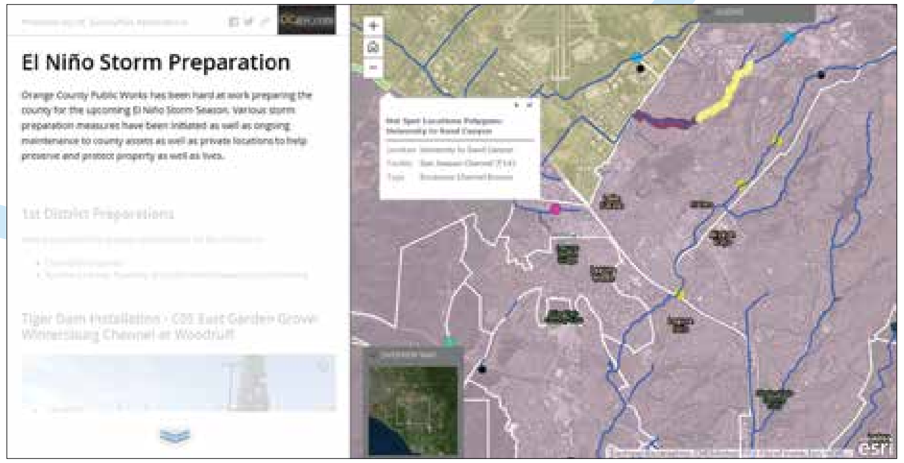
To handle the immediate demands of disasters, governments and other organizations have expanded the use of GIS to support the entire emergency management cycle from risk assessment and planning to mitigation and preparedness. In the intervening 18 years since the last major El Niño event, Esri software has expanded beyond desktop analysis to a platform that includes server, cloud, and mobile.

Analysis now benefits from the big data tools in the ArcGIS platform and its integration with R (the R Project for Statistical Computing). Data sharing between agencies enabled by ArcGIS Online, Esri's cloud-based solution, and ArcGIS Open Data have vastly increased the information that can be considered in addition to the incorporation of real-time data from sensors, such as rain gages.

Two decades ago, the results of GIS analysis were disseminated through paper and static online maps. While these maps could be rapidly produced, they were dependent on the update cycle and could not provide the most current information. Because they lacked interactivity, these maps—generated to answer one set of questions—could not be queried to answer new questions spawned by response situations in constant flux or address additional scenarios when working on planning, mitigation, or preparedness efforts.

This Esri Story Map app created by the humanitarian organization DirectRelief illustrates potential threats to vulnerable populations in California.





Orange County Public Works has been preparing the county for the upcoming El Niño event and documented its efforts in this story map.

ArcGIS for Flood gives organizations tools for responding to El Niño such as this configurable app for modeling the impact of flooding on special populations and property.

ArcGIS Online answers the need for interactivity, immediate updates, easy collaboration, and rapid dissemination of information to other agencies and the public. Organizations are also using Esri Story Map apps for communicating, whether it is potential risks or the current state of response efforts. DirectRelief, a worldwide humanitarian organization, has used this approach for keeping the public apprised of El Niño hazards. It created a story map communicating the health risks of California's most vulnerable populations and sharing its analyses evaluating the contributions of drought and recent wildfires to the state's peril.

Situational awareness is the key to effective emergency management, and again, ArcGIS Online supports greatly enhanced communication during a disaster. The easily configured Operations Dashboard for ArcGIS app provides a real-time common operating picture (COP) for monitoring rapidly changing events, allocating resources in response, and maintaining an overview of the situation. The dashboard works with GIS tools for fieldwork, such as Collector for ArcGIS, so that responders can communicate conditions immediately to emergency managers and everyone else responding to the event.

These same GIS-based communication tools aid activities immediately after an event to assist victims, speed relief, and limit secondary damage. The existing GIS infrastructure at many utilities aids short-term recovery by supporting the restoration of the systems that supply water, food, sanitation, and power.

The longer-term task of rebuilding a community that may take months or years can be guided by geodesign. This strategy for designing more livable communities makes extensive use of GIS tools to model and test alternative designs. This approach can help planners create resilent communities that better withstand extreme weather conditions and other challenges likely to result from climate change.

In response to the immediate threat of flooding from El Niño conditions, Esri recently developed ArcGIS for Flood. This suite of configurable apps, software, and professional services helps communities safeguard people and property and integrate a geographic dimension into emergency planning, response, and recovery activities associated with responding to the flooding.

ArcGIS for Flood addresses the entire disaster management cycle from the creation of authoritative flood extents to tools for identifying at-risk assets and populations to communicating evacuation and shelter information to the public. It helps communities minimize the effects of floods and speed recovery. More information about ArcGIS for Flood is available at esriurl.com/arcgisforflood.

Flood Forecast Maps Safeguard Belgium

By Jim Baumann, Esri Writer

Flanders, a region in Belgium, has historically suffered from flooding. This photo shows flooding from the Dender River in 2010.

Vlaamse Milieumaatschappij (VMM) uses real-time measurements taken every 15 minutes, along with meteorological forecasts, as inputs for hydrologic models in the flood forecasting systems.

The environmental agency in Flanders has built an advanced flood forecasting system that uses real-time measurements and meteorological forecasts as input for hydrologic models. The real-time flood forecast maps it publishes using ArcGIS for Server keep residents aware of potential danger by showing the maximum extent and impact of flooding.

Located in the Low Countries of northwestern Europe, Belgium—particularly Flanders, a region in Belgium—has historically suffered from flooding. Records indicate that major storm surges between the thirteenth and seventeenth centuries destroyed more than 100 coastal villages in the region. Portions of Flanders are at or below sea level and contain a dense network of rivers that increase the potential for flooding during periods of heavy rainfall and storm surges.

Over the years, the Flemish government has implemented flood control projects, including a comprehensive dike and canal system, in an effort to protect the region. However, as a result of massive floods in 1998, when the Demer River overflowed its banks and caused severe damage, the government began exploring methods of flood prediction.

"We began building a simple forecasting system for the Demer River in 2002," said Kris Cauwenberghs, head of the flood management unit of the Flanders Environment Agency, or Vlaamse Milieumaatschappij (VMM). "The system generated predicted stream discharge hydrographs showing the variation of water discharge over time." The modeled Demer River is about 100 kilometers in length, and the hydrographs were only used for internal purposes at that time.

Since then, the VMM has developed and deployed an advanced flood forecasting system throughout Flanders that monitors more than 4,000 kilometers of the region's waterways. To publish the flood forecast on the web, VMM used ArcGIS for Server Enterprise Advanced as well as ArcGIS Image Extension for Server, ArcGIS Spatial Analyst for Server, and ArcGIS 3D Analyst for Server. This software stack is used to manage, analyze, and serve the massive amounts of data collected by the flood forecasting system.

To fully comprehend the dynamics of the waterways in Flanders, surveyors have spent the past 15 years extensively mapping them by creating cross-sections of the rivers every 50 meters. The data collected includes detailed information on the profile of the riverbed and riverbanks as well as the dimensions of bridges, locks, water reservoirs, and other infrastructure along the waterways. This data is included in the forecasting system for monitoring and flood assessment purposes.

Real-time measurements are taken every 15 minutes and, together with meteorological forecasts, are used as input for hydrologic models. The hydrologic models in the flood forecasting systems are used to predict the volume of the water discharge during a specific period of time. The outputs from the hydrologic models are also used to feed the VMM's hydrodynamic models. This data is seamlessly merged with data from other Flemish organizations for advanced impact analysis and then shared with those agencies responsible for water management and emergency planning.

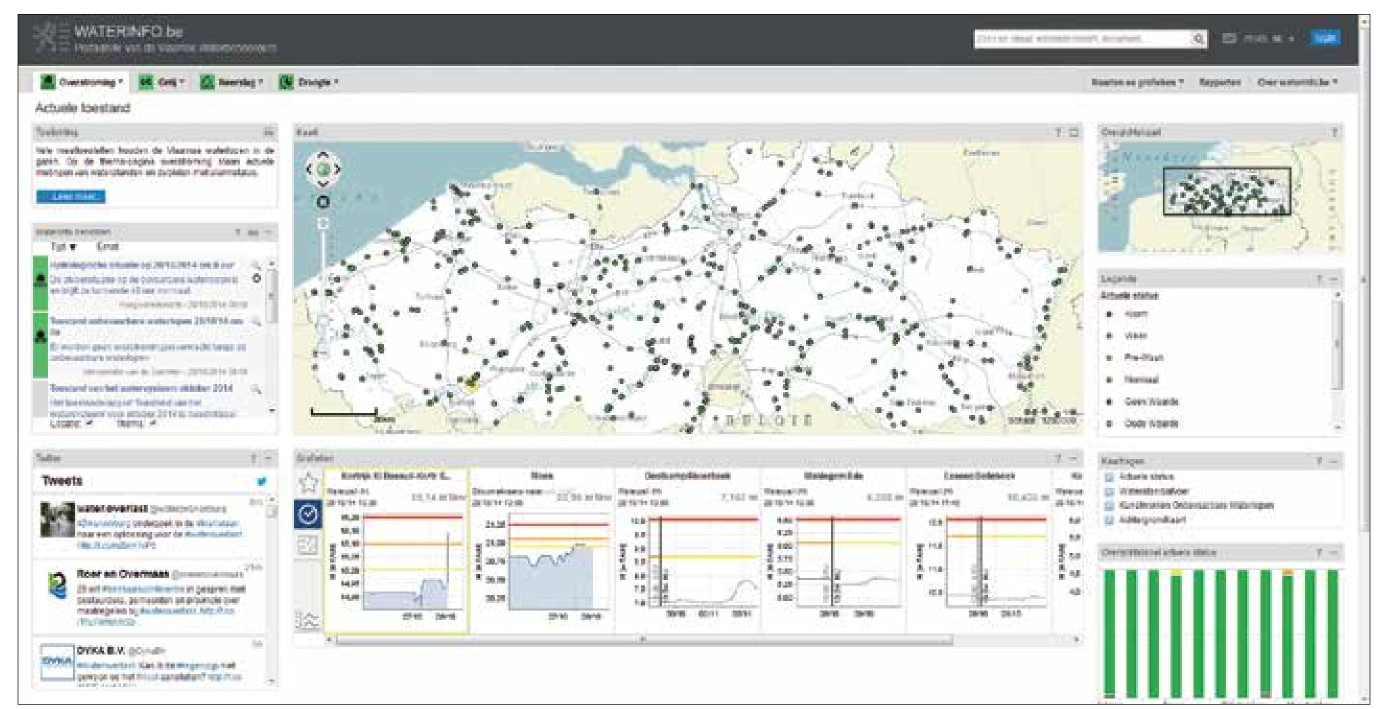
"Originally, we used deterministic forecasting for our predictions," said Cauwenberghs. This early flood-modeling procedure was based on analyzing existing conditions and single meteorological forecasts. Today, the VMM uses ensemble forecasting. This type of forecasting employs a methodology based on repeated random samplings of water levels, flows, and precipitation to produce hydrodynamic models for the prediction of potential flooding outcomes. "Ensemble forecasting allows us to deliver flood forecasts 10 days in advance, and VMM can now confidently publish its real-time flood forecast maps to keep its residents aware of potential danger," concluded Cauwenberghs.

The resultant flood maps can be used not only for evaluating the predicted maximum flood extent but also for determining the impact of a potential flood, such as which houses and streets will be flooded, so that precautionary measures can be taken.

To identify flood-prone areas, the VMM creates simulations by combining its hydrodynamic models with a digital elevation model and the river cross-sections and related infrastructure mapped by the surveyors. These simulations mimic the physical characteristics of a waterway by imitating how water flows through a specified riverbed. This provides a comprehensive overview of the entire river and facilitates a highly accurate prediction of the extent of flooding when a river overflows its banks. The model is calibrated using data collected from the historical storms that have struck the region.

"Using the same hydrodynamic models, we can also produce flood hazard maps in an offline mode for insurance risk purposes," said Cauwenberghs. "Instead of the actual flood extent, these maps show the probability of flooding based upon statistical analysis and can be used for spatial planning purposes or insurance risk calculations."

To explore the Flanders environmental agency's flood forecasting system, visit www.waterinfo.be.



A Real-Time Flood Warning System

By John K. Dorman, North Carolina Division of Emergency Management, and Neal Banerjee, ESP Associates P.A.

Since its inception 10 years ago, a North Carolina network of gages that collect rain and stream flow information has evolved into a sophisticated system of gages and integrated technologies that collect, analyze, map, and communicate flood hazard extent and estimated damage in real time through a powerful web interface.

North Carolina established the North Carolina Floodplain Mapping Program (NCFMP) to better identify, communicate, and manage risks from flood hazards within the state in response to the devastating flooding caused by Hurricane Floyd in 1999. This led to the establishment of the Flood Inundation Mapping and Alert Network (FIMAN) to provide real-time flood information throughout North Carolina.

FIMAN is a unique component in NCFMP's program. Whereas traditional floodplain maps are based on model simulations of probabilistic storm events, such as a 100-year storm event, FIMAN provides actual storm-specific rainfall and stream/flood information based on a system of measurement stations (i.e., gages) located throughout the state.

This system integrates existing gages maintained by the US Geological Survey and other agencies with state-owned gages, resulting in an overall network of approximately 550 gages. Gage readings are typically recorded and transmitted every 15 to 30 minutes. The goal of the FIMAN system is to reduce the loss of life and flood-related property damage by providing emergency managers and the public with more timely, detailed, and accurate information.

The FIMAN network utilizes multiple technologies to collect and feed real-time data to GIS servers for dissemination. Data collected at the gages through sensors is transmitted by radios or satellite, retrieved and processed by special software, and then stored into an enterprise GIS database. Custom tools then evaluate readings and assess potential flood conditions. During flooding conditions, the tools will calculate estimated impacts and send automated alerts. Esri ArcGIS for Server is used to display the locations and query real-time gages and flood impact information in a custom web application.

Determining Real-Time Flood Conditions and Impacts

One of the most powerful aspects of FIMAN is its ability to not only measure and display gage information but also analyze, map, and communicate flood risks in real time. As gage readings are loaded into the central GIS database, they are first compared with predefined thresholds and the previous readings to assign a general flood condition (major flooding, minor flooding, no flooding) and determine the trend of the flood condition (e.g., increasing or decreasing). If a gage is identified as being in a flood condition, the database runs tools to develop estimated flood inundation boundaries and compute flood impacts.

One inherent challenge with gage-based warning systems is that they only give information at the specific location of that gage. Gages are expensive to install and require resources to maintain them. If they are present at all, gages are typically located sporadically along a stream, often many miles apart.

Thus, there are often long sections of stream that may be vulnerable to flooding but for which no information is available. NCFMP uses an innovative approach for overcoming this challenge that results in the automated generation of seamless flood inundation boundaries and subsequent impact analysis between gages and along multiple streams in one process. Collectively, this set of tools used to analyze and map real-time gage readings is referred to as NexFIM.

How NexFIM Works

NexFIM is built on tools that leverage multifrequency flood hazard information and vulnerable asset information from the NC FLOOD and NC RISK databases that NCFMP maintains as part of its overall program. During a flood event, NexFIM algorithms calculate real-time storm event probability for each stream gage in the system. The tools then use probability raster datasets to produce real-time flood inundation layers within minutes of receiving the gage telemetry. The seamless flood inundation boundary is regenerated with every gage reading. Thus, the system has the ability to track the wave of a storm event as it moves through a river system. In addition, the tools time-stamp and archive each inundation boundary so that an overall maximum flood extent associated with a given storm event can be mapped.

Once a flood inundation boundary is developed, NexFIM tools overlay the flood inundation boundary with existing structure information (such as building type, value, and first-floor elevation) stored in the databases to identify impacted buildings and assign storm event probabilities. Estimated damage for each building is then calculated by the tool. Along with individual building depths and damages, the tools calculate rolled-up damage summary statistics for logical categories such as occupancy type, community, or stream.

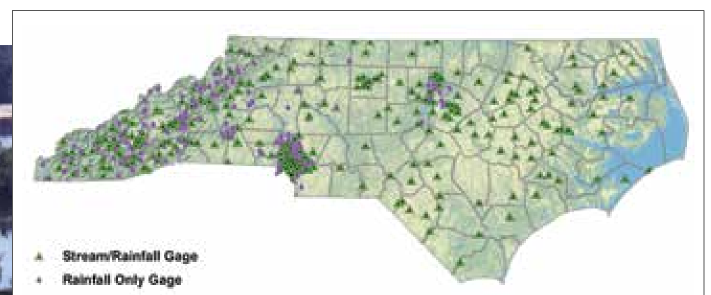
Flood Warning and Impact Assessment

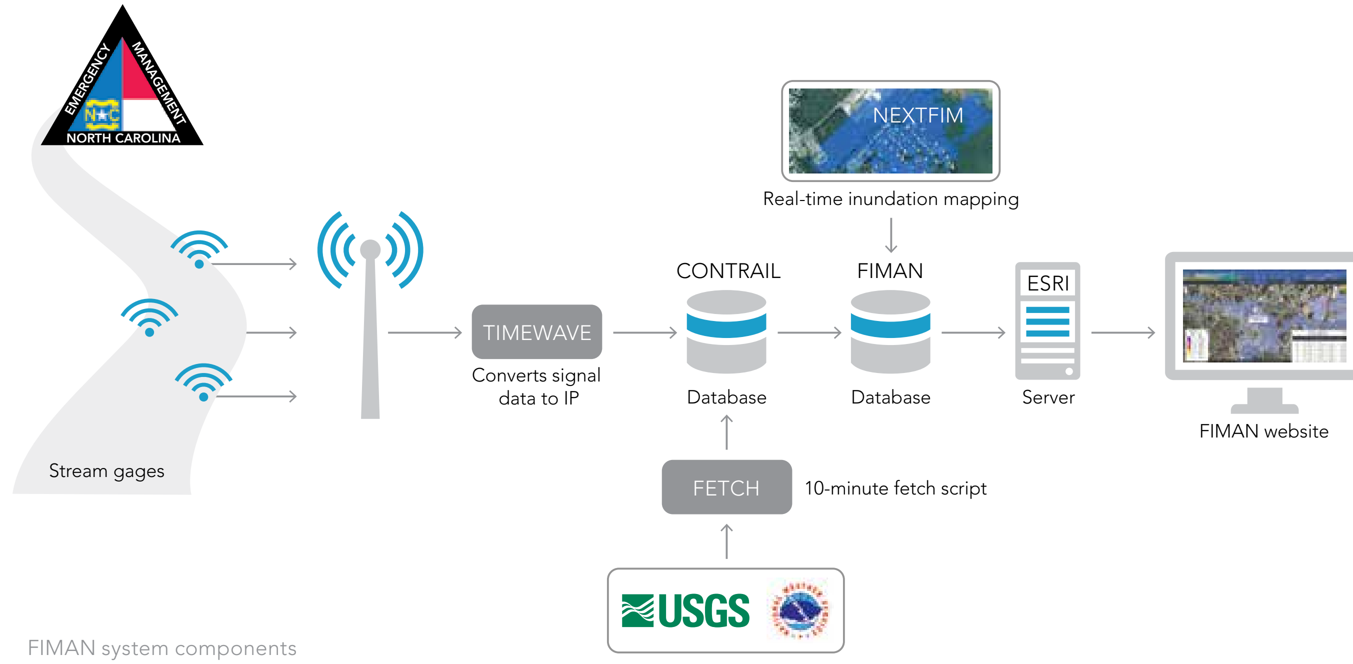
FIMAN is a sophisticated system of integrated technologies, datasets, and tools. However, one element that is critical to meeting the objectives of the system is the ability to effectively communicate information to emergency managers and the general public.

NCFMP has developed the FIMAN web application to view and

The devastating flooding caused by Hurricane Floyd in 1999 led to the establishment of the North Carolina Floodplain Mapping Program. This photo shows portions of Edgecombe County engulfed by floodwaters. Photo by Dave Saville/FEMA News Photo.

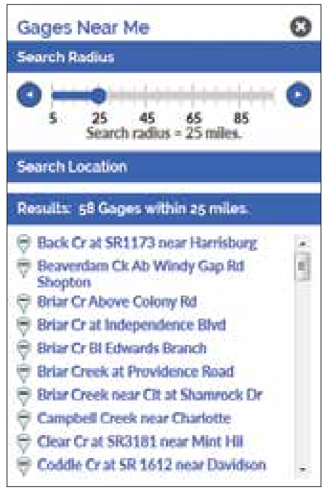
North Carolina Flood Inundation Mapping and Alert Network (FIMAN) gage network





FIMAN system components

FIMAN workflow



Dialog displaying nearby gages based on location search

disseminate the information. The application site uses responsive design and consistent modeling techniques, which allows it to be efficiently accessed from desktop, laptop, or any mobile device. The site also integrates common GIS base data and geocoding services as well as layers such as live weather radar feeds. The FIMAN site has two view themes—the Gage view and the NexFIM view. The view themes differ in focus and target audience, but both are accessible to all site visitors.

Gage View

The Gage view is intended for the general public to learn about flood conditions and alerts in an area of interest. An interactive map displays pins showing the gage status and trend of all gages in the state. Users can find gages of interest using their current location, view gages within a search radius, or search by river basin or gage name. Selecting a gage displays the most recent stage, flow, and predicted risk information. Where available, forecast information from the National Weather Service is also displayed. What-if scenario tools show potential flood damage/impact estimates. For example, these tools can show what areas will flood if the gage gets to a certain level. Users can also sign up for automated email notifications when a gage of interest changes flood state.

NexFIM View

Whereas the Gage view focuses on information at a specific gage of interest, the NexFIM view provides real-time and scenario flood information for an entire river system using the NexFIM computational algorithms. Using a pull-down list, users can select a river system of interest that has been processed in the FIMAN system. The viewer zooms to the river system and displays an outline distinguishing all the gages included in the selected river system.

If gages in the selected river system are experiencing flooding, seamless flood inundation areas will be depicted in the viewer and will be updated with every new gage reading. Similar to the Gage view, the NexFIM view lets the user view information for a number of scenario storm events such as a 25-year flood event. In addition, the viewer provides flood information for select historic events, such as Hurricane Floyd, that have been processed.

The NexFIM view also provides powerful visualization of the flood impacts by displaying impacted buildings color-coded by depth of flooding and tabulated building damage estimates. The user can click on an individual building for specific information on that building such as building type, flood depth, and estimated damages.

FIMAN in Action—Hurricane Joaquin

In the first week of October 2015, the combination of Hurricane Joaquin passing to the east and a stalled low-pressure system produced historic rainfall totals and subsequent flooding in portions of the Carolinas. The storm, which had rainfall totals ranging from 3 inches to over 20 inches over a three-day period, resulted in more than 20 fatalities and damages estimated in the billions of dollars.

Although North Carolina was spared the extreme rainfall experienced in South Carolina, the storm resulted in significant flooding along the coast and eastern counties. FIMAN was used by the State Emergency Operations Center throughout the storm to monitor flooding conditions, assess potential impacts of flooding based on weather forecasts, and target the deployment of emergency response personnel and resources. FIMAN served as an invaluable tool in communicating risk to public officials and the public.

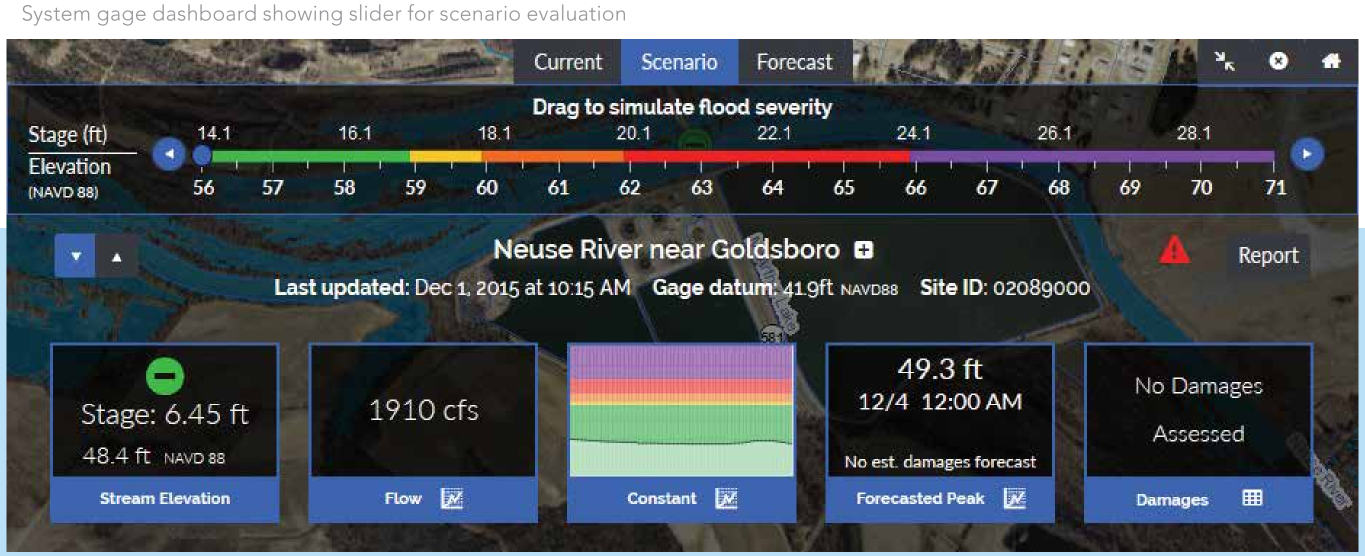
Building on the Program

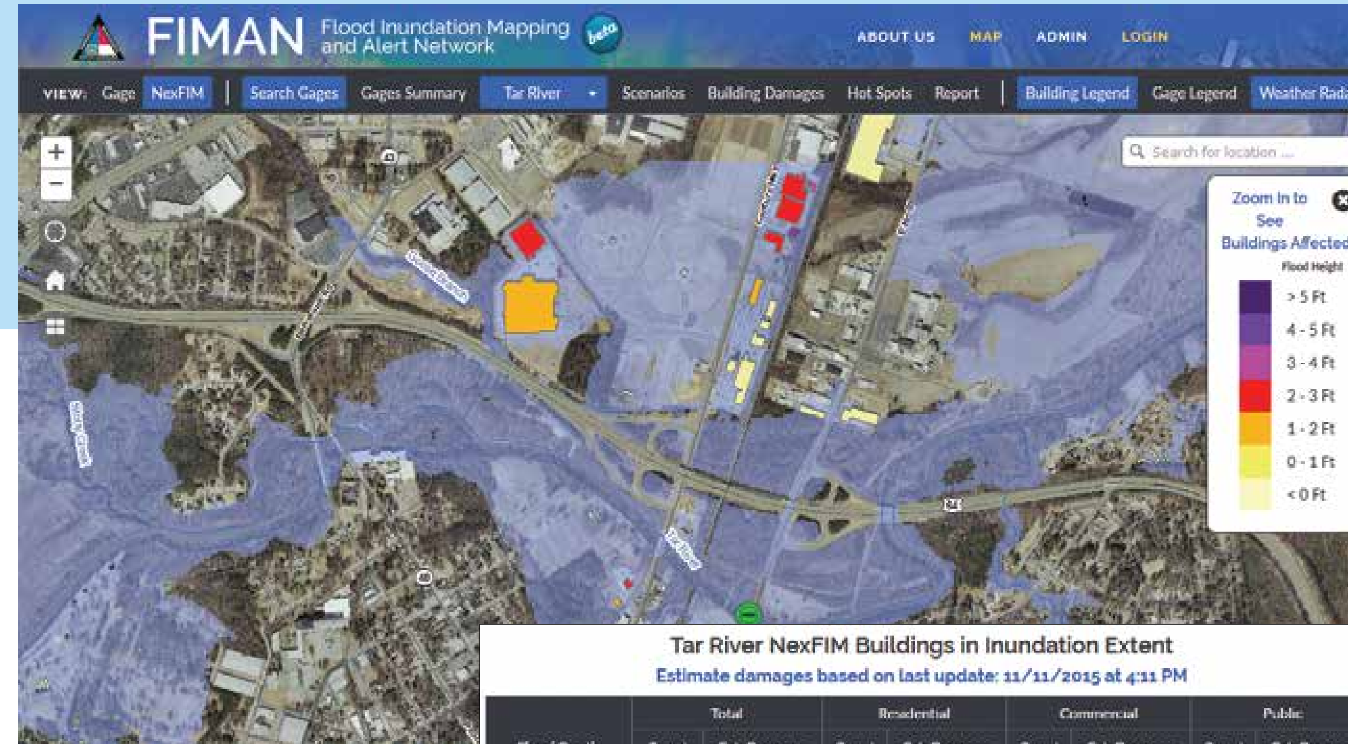
FIMAN relies on physical rain/stream gages and databases with flood hazard and vulnerable asset information to identify and communicate current and forecast flood risks. NCFMP is continuously reviewing, adding to, and updating this information. Although FIMAN contains a relatively dense network of gages, NCFMP will continue adding new gages based on identified need and available funding.

As part of its regular flood and risk maintenance, NCFMP is also collecting new data and updating flood and risk information. For example, NCFMP is currently collecting high-resolution (two points per meter) lidar for the entire state. This new topographic data will be used to verify and/or update flood and risk information. As new gages and updated flood and risk information are developed, the data from them will be integrated into FIMAN, further enhancing geographic coverage and accuracy of real-time flood information.

For more information, contact John K. Dorman at John.Dorman@ncdps.gov or Neal Banerjee at nbanerjee@espassociates.com.

System gage dashboard showing slider for scenario evaluation





Tar River NexFIM Buildings in Inundation Extent

Estimate damages based on last update: 11/11/2015 at 4:11 PM

Flood Depth	Total Count	Total Est. Damages	Residential Count	Residential Est. Damages	Commercial Count	Commercial Est. Damages	Public Count	Public Est. Damages
Sub Structure	528	$10,137,000	454	$3,917,000	71	$6,200,000	3	$30,000
0 - 1 ft	212	$5,262,000	170	$2,383,000	39	$2,811,000	3	$68,000
1 - 2 ft	298	$23,537,000	245	$3,315,000	50	$20,160,000	3	$62,000
2 - 3 ft	197	$12,248,000	139	$3,229,000	56	$9,009,000	2	$10,000
3 - 4 ft	116	$9,136,000	72	$2,430,000	42	$6,684,000	2	$22,000
4 - 5 ft	52	$1,919,000	28	$815,000	23	$1,002,000	1	$102,000
> 5 ft	97	$5,249,000	42	$1,801,000	52	$3,379,000	3	$70,000
TOTAL	1500	$67,487,000	1150	$17,889,000	333	$49,246,000	17	$353,000

Impacted building visualization and table supplying estimated damages

About the Authors

John Dorman, the assistant state emergency management director for North Carolina, also serves as the director of the Risk Management Section in the North Carolina Division of Emergency Management. He is responsible for the development, implementation, and management of all information technology infrastructure, geospatial data, and applications.

Dorman previously served as the statewide planning administrator for the Office of State Budget, Planning, and Management. Following Hurricane Floyd in 1999, North Carolina petitioned the Federal Emergency Management Agency (FEMA) and became the first state in the nation designated as a partner in the Cooperating Technical Partners Program. This designation led to the creation of the North Carolina Floodplain Mapping Program, which was placed under Dorman's supervision until 2001, when the program was moved to the Department of Crime Control and Public Safety to support emergency managers, first responders, and law enforcement organizations.

In 2005, Dorman was given the responsibility for managing all information technology infrastructure and applications in the Division of Emergency Management. He graduated from North Carolina State University with a degree in political science.

Neal Banerjee, a designated professional engineer and certified floodplain manager, is a water resources department manager with ESP Associates P.A. in Charlotte, North Carolina. He has more than 20 years of experience in water resources engineering and GIS including engineering analysis, GIS/database analysis and customization, and program management on a variety of floodplain studies, master plans, capital improvement projects, development projects, and data/application development projects. He holds a master's degree in civil engineering from the University of North Carolina, Charlotte, and bachelor's degrees in civil engineering and anthropology from the University of Illinois.

Dutch Time Travel

During the 2015 Dutch Esri GIS Conference, the Netherlands' Cadastre, Land Registry and Mapping Agency, known as Dutch Kadaster, presented the Dutch people (and the world) with a website that marks the 200th anniversary of Dutch topography by making 200 years of maps of the Netherlands available to the public.

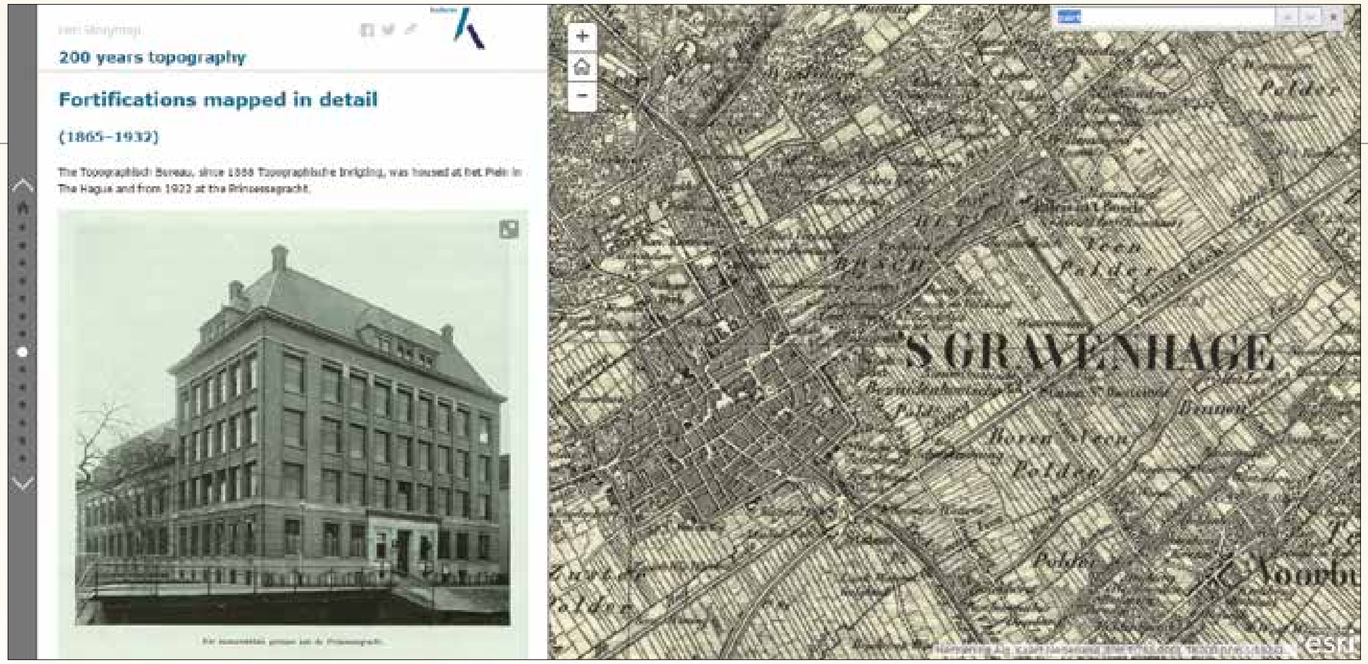
Dutch Kadaster, which operates under the Minister of Infrastructure and the Environment, collects and registers administrative and spatial data on property and the rights associated with not only real property but also ships, aircraft, and telecom networks. Dutch Kadaster is also responsible for national mapping, maintaining the national reference coordinate system, and advising on land-use issues and national spatial data infrastructures.

Conference attendees enthusiastically responded to the mapping website, topotijdreis.nl, which features land reclamation, urbanization, land allocation, and other maps showing the transformation of the Dutch landscape.

Making It Scalable and Fast

Esri Nederland B.V. worked with Dutch Kadaster to create digital versions of the maps and a website to easily view them. Joris Bak of Esri Nederland, who was the content lead on this project, said ArcGIS API for JavaScript was used to create the website. The API offered handy building blocks for developing the application, such as a search function that operates based on the Basisregistratie Adressen en Gebouwen (or Basic Registration of Addresses and Buildings, or BAG). The API also makes sure the application works seamlessly in environments from browsers on desktops to mobile devices. It uses the latest HTML5 and CSS3 standards, making the app more responsive.

The topotijdreis.nl website lets visitors view the transformation of the Dutch landscape from the 1800s to the present, shown in these maps from 1850, 1950, and 2015.



The Esri Story Map 200 years topography outlines the history of Dutch topographic mapping.

Design Challenges

The biggest challenge when designing topotijdreis.nl was making the display and navigation through 200 years of historical maps easy and enjoyable. The app's interface is simple but highly functional. A time slider on the left side can be used to quickly locate the maps available for a specific year. Buttons control zoom-in and zoom-out. Users can zoom in to a specific location on any map currently displayed by using their current location or entering a location in the search box.

Tiled services were chosen for making the maps accessible online. Preparing so many tiled services was a lot of work, but with the prospect of reaching such a large audience with this web app, performance and scalability considerations more than justified the effort required.

Over the course of five weeks, Esri Nederland's content team inventoried the thousands of historical maps provided by Dutch Kadaster. Original maps were scanned and then converted to tiles using ArcGIS for Desktop. One tile is equivalent to an image that is 256 x 256 pixels. Several tiles are loaded to fill the screen.

The tiles were uploaded to ArcGIS Online as more than 200 tile packages and unpacked as tile services. When this process was finished, the tiled maps took up about 1.2 terabytes of storage space. By using tiled services on ArcGIS Online, the site could take advantage of the speed and automatic scalability of ArcGIS Online to handle periods of peak usage.

Because the topotijdreis.nl website was instantly and enormously popular, it received a great deal of traffic. Choosing ArcGIS Online and tiled services was critical to the website's success because ArcGIS Online was able to scale up its services to accommodate a flood of visitors. On the first day, more than 13.5 million tile requests per hour were made. Over the next two days, the website had more than 200,000 unique visitors. In the first week after its release, more than 300 million tile requests were received for the historical maps, and at times ArcGIS Online served as many as 4,000 tiles per second.

Through Cartographic History

Until the end of the 18th century, the Netherlands had no central government. A set of nationwide topographic maps had not been produced, and only portions of the country had been mapped. However, the need for topographic maps was great, not only for military reasons but also to aid in the management of dikes and waterways. In 1798, the systematic and standardized mapping of the country began.

Before the topotijdreis.nl website was created, most of these important maps were either not available or were not readily accessible by the public. To peruse these historic maps, visit topotijdreis.nl. To learn more about the history of Dutch topographic mapping, search on "200 years of dutch topographic mapping" to locate an Esri Story Map called 200 years topography.

This article was provided by Esri Nederland.

Having Fun

While meeting a serious need

By Carla Wheeler, *ArcWatch* Editor

"Spot" the Hydrant looks nice and clean after a snowfall in Minnesota, thanks to adopter Mark Frederick. Photo courtesy of Mark Frederick.

If you drive north on Idaho Avenue North in Brooklyn Park, Minnesota, and go about a block past 71st Avenue, you will spot a red fire hydrant on the left side of the street. But it's not just an ordinary fire hydrant. It's Squirt, named by Brian, the man who adopted the hydrant using the city's new online Adopt a Hydrant mapping app.

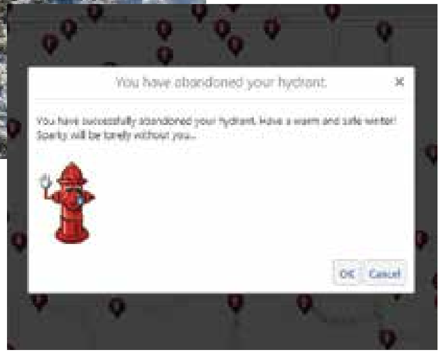
Brian assumed responsibility for Squirt, promising the Brooklyn Park Fire Department that he would keep the hydrant clear of snow and ice during what's likely to be a long, cold, snowy Minnesota winter. The agreement is informal and nonbinding—Brian could abandon Squirt simply by clicking his mouse on the Abandon Me link. But city GIS coordinator John Nerge said that rarely happens in the civic-minded city of 78,728 people, located 10 miles northwest of Minneapolis, unless someone moves.

The City of Brooklyn Park's Operations and Maintenance Department is tasked with clearing snow from the hydrants. Being able to easily access water quickly during a fire can be a matter of life and death. "Extra seconds matter in saving a property or a life," Nerge said.

Hydrants covered by snow or surrounded by high snowdrifts or banks give firefighters a big headache, sending them scrambling—possibly in the dark—to clear a pathway to the hydrant and then shovel the snow off of it. Because it's difficult to quickly remove snow from all 3,500 hydrants following a winter storm, fire officials sought out the public's help by developing a civic engagement app that encourages hydrant adoption. "The goal of this program is mainly to help us save lives," said Stephanie Pemberton, a program assistant for the Brooklyn Park Fire Department.

A Fun and Family-Friendly App

With this in mind, Pemberton pursued the idea of an Adopt a Hydrant program for Brooklyn Park. While other cities around the country have them, she thought hosting a mapping app would provide a great way to engage more people in the idea of personally caring for hydrants. "Some people are shoveling without officially adopting on the app, but we thought this was a new way to cause interest and engagement in a day and age of apps and tech," Pemberton said.



Even if a hydrant adopter must do the unthinkable—abandon a hydrant—that person receives a friendly farewell message from its sad hydrant.

She did some research online and learned about the City of Boston's Adopt a Hydrant mapping app, created by Code for America, and found the code for the app in the GitHub repository. The app was created using the Ruby on Rails framework with a Postgres database.

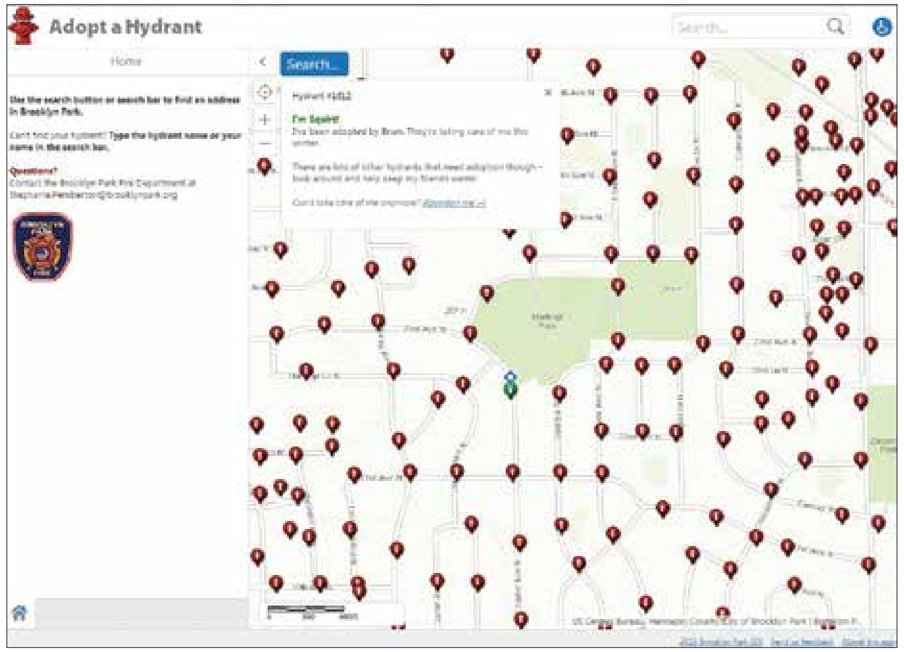
When contacted by Pemberton, Nerge, (an unapologetic nondeveloper) said he decided to use the software and services he had available instead—Geocortex Essentials and ArcGIS for Server. Nerge supervised Kaela Dickens, a GIS intern in Nerge's office, who used Geocortex Essentials software to create the customer workflows and app components. These componenets included the text introducing the app to users; the address search box; the hydrant symbols; the adopted hydrant's back story including its name; other search tools to find and select a hydrant; the Adopt me! links; the form that collects people's names, email addresses, and hydrant names; and everything else the user or administrator needs to interact with in the app.

The online map, an HTML5 app built using Geocortex Essentials software from Esri partner Latitude Geographics, uses basemaps and transportation layers from ArcGIS Online and runs on Esri's ArcGIS for Server. An ArcGIS for Server service records and stores information on hydrant adopters.

The app is user-friendly. People just open the app in a web browser, type their home or work address in a search box, and click Find Address, and the map automatically zooms to the location. As users zoom out from the address, the hydrants available to adopt appear as red icons. Fire hydrant icons that are green have already been adopted, while those pending adoption are yellow.

Each red hydrant on the map has a number and a pop-up that displays a message that reads "Hi, I'm available for adoption," and a blue link saying "Adopt me!" That link takes people to a form that asks for their name, email address, and a name for the hydrant.

The app was designed to be family friendly. Dickens, who has served as an intern for Brooklyn Park for a year and a half while she earns a master's degree in public policy at a local university, wanted the app to have lighthearted tone. She used simple language in the text of the pop-ups to appeal to parents who have small children and might be interested in adopting a hydrant.



The red icons indicate which fire hydrants are available for adoption. The pop-up on the green icon includes a message from Squirt, a hydrant that has already been adopted.

She wrote a standard reply for each hydrant. For example, hydrant #36 (also known as Sparky) generated this message when it was adopted: "I've been adopted by Hoidal. They're taking care of me this winter. There are lots of other hydrants that need adoption though—look around and help keep my friends warm! Can't take care of me anymore? Abandon me."

If Sparky the Hydrant is abandoned, Hoidal will receive this automatic message generated by the app: "You have successfully abandoned your hydrant. Have a warm and safe winter! Sparky will be lonely without you." A cartoon drawing of Sparky waving good-bye with a tear coming out of his eye is included.

"It seems people are having fun with it," Nerge said. "That was the hope." Joining Squirt and Sparky on the front line of the fire department's army of hydrants are Viper, Batman, Captain Maximus, Diego, Olaf the Snow Hydrant, Miss Scarlett, Inigo Montoya, The Little Hydrant that Could, and Joe's Flow (adopted, of course, by a guy named Joe).

Pemberton uses an administrator version of the app to send out confirmation emails when adoptions have been approved (or rejected, if the proposed hydrant name is deemed racy or offensive). She also will notify hydrant adopters if snow is forecast for the Twin Cities, gently reminding people to remove snow from the hydrants soon afterward. She personalizes the messages, too, writing questions such as, "How did Spot do in the snowstorm?" or comments such as, "I hope Olaf is keeping warm."

Working with Residents

Adopt a Hydrant, one of the apps in the city's gallery of 31 maps, offers a way for the city to communicate directly with residents. In the future, the staff hopes that the app and others like it will help get people involved with city government and foster civic engagement.

"The motto at Brooklyn Park is, 'We don't do things to people. We want to do things with people,'" said Dickens.

Of the 3,500 hydrants in the city, about 45 have been adopted since the app's launch last year, and that number is expected to climb this winter as a public awareness campaign goes into full swing. While the initial adoption numbers might seem like a drop in the bucket, even a budding program like this is valuable to firefighters, who depend on easy access to hydrants when fighting a fire. The city plans to build a mobile mapping app that includes the location of all the adopted hydrants, making it easier for firefighters to find ones they know will be cleared of snow.

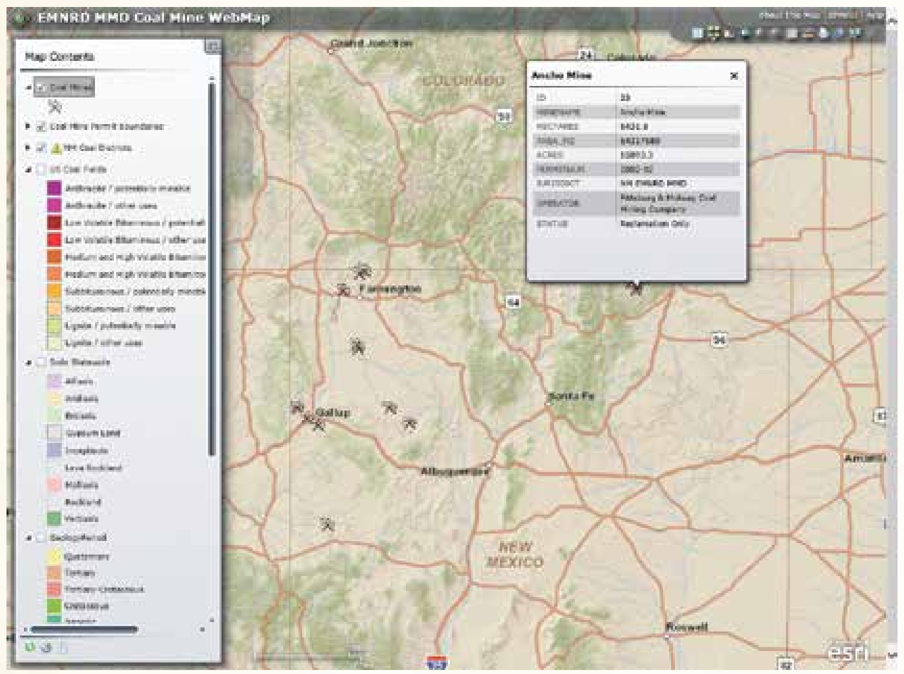
"We've always had Good Samaritans shoveling out hydrants," Nerge said of the residents. "This was an opportunity to create a program that would inspire neighborhood pride and be fun by naming the hydrants."

Congratulations!

The City of Brooklyn Park won a Special Achievement in GIS Award at the 2015 Esri User Conference for its innovative use of and best practices for using the Esri ArcGIS platform. In just three years, the city went from posting nine PDF maps to hosting 31 mapping apps on its website. The map gallery, managed and hosted in ArcGIS Online, includes a time animation app of traffic accidents; a voting information app; and an Esri Story Map Tour of the winning gardens in the Summer Blossom program, which encourages beautifying the city through landscaping.

Managing Mining from Exploration to Reclamation

By Barbara Leigh Shields, Esri Writer



In terms of land area, New Mexico—with 121,000 square miles—is the fifth-largest US state. Overseeing mine operations across such a large area is no small achievement.

The New Mexico Energy, Minerals and Natural Resources Department (EMNRD), Mining and Minerals Division (MMD), ensures that mining operations, from exploration to reclamation, are conducted responsibly. MMD uses Esri GIS to process mining operation and exploration permit applications and report economic impacts. Maps provide a baseline for analyzing activities and disturbances by mining operations across the state's vast landscape.

GIS helps MMD track mining activity throughout the state as well as enforce reclamation regulations for surface mines and abandoned mine lands. It tracks land change, maps mine impacts, and provides guidelines for mine reclamation projects and all mandated environmental and cultural assessments before projects are designed.

MMD currently uses Microsoft SQL Server integrated with ArcGIS for Server to manage most mine information, its geodatabase, and its web map applications. The division is transitioning more of its geospatial data to the Esri platform. The geodatabase includes data from the state's resource GIS clearinghouse, mine operators, and others, as well as data generated in-house.

"GIS helps the Mining and Minerals Division prioritize where it should spend money on surface reclamation projects," said Linda S. DeLay, GISP and remote-sensing specialist at MMD.

DeLay employs GIS for prioritizing cleanup activities. She analyzes the location of legacy uranium mines and prioritizes them for reclamation based on proximity to streams, agricultural sites, urban areas, and wells. She uses ModelBuilder, an application in ArcGIS for Desktop used to create, edit, and manage models, and a weighted overlay GIS model to map reclamation priorities. Using this methodology, she created the New Mexico Legacy Uranium Mines map, which helps decision makers decide where to allocate resources. She has presented this map at meetings of MMD and its sister agencies as well as a national conference.

The New Mexico Environment Department has a stake in making sure mines operate conscientiously. GIS supports MMD's collaboration with the Environment Department to consider permit applications. Maps make it easier for the agencies to review and comment on mine permits and closeout plans as well as ensure that environmental standards are included in the application. The department also works with MMD to monitor mining reclamation activities.

Resourceful MMD staff members keep operating costs down, in part by acquiring data at no or low cost and by forming geospatial or technical sharing partnerships. To monitor coal mine reclamation, MMD applied for a grant from the Office of Surface Mining and Reclamation Enforcement (OSMRE) Western Region to acquire WorldView-2 satellite imagery. Using this imagery along with on-the-ground vegetation surveys, DeLay is creating vegetation change detection maps for the Vermejo Park Ranch abandoned coal mine town reclamation project to aid reclamation specialists in evaluating revegetation and wetland mitigation.

While satellite imagery provides a close-up picture of surface mines, GIS renderings of lidar data offer a highly detailed 3D perspective. These sophisticated 2D and 3D maps reveal the condition of an area prior to the commencement of mine operations.

To assess the impact to the vegetation and terrain around the El Segundo coal mining operation and another proposed mine, MMD used GIS to document baseline landform conditions. The Coal Mine Reclamation Program orchestrated the acquisition of lidar data for two 25-square-mile areas that had been captured prior to mining operations. It used first return lidar data to render vegetation density images and bare earth returns to model the terrain.

The lidar rendering is a blueprint for what the mining company will need to do to reestablish vegetation to its initial condition when it closes the mine and restore the terrain's original contour, a process called geomorphic reclamation. It is a landscape reconstruction technique that attempts to re-create the original surface surrounding a mined area and replicate its natural drainage patterns.

Activities associated with geomorphic reclamation may include redistributing, removing, and/or burying the mine waste as well as reforming stream channels to a more natural pattern and eliminate movement of waste into watershed drainages. To map the new terrain design, GPS devices are attached to earthmoving equipment.

Staff have found a less expensive way to capture data by using an unmanned aircraft system (UAS). A compact camera mounted to a Trimble UX5 fixed wing aircraft takes a large number of overlapping orthophotos. Photogrammetric processing of these images generates a point cloud of x-, y-, and z-values rendering a 3D topographic model.

MMD used this technique and GIS to create a topographic model of a stream restoration project at an historic coal mining town. Staff calculated the heights of the vegetation by attributing the points with the photo RGB values and classifying points as ground or vegetation, then subtracted the ground elevations. To spot-check the accuracy of the remote-sensing data, staff went into the field to measure the heights of a sample of vegetation for comparison.

In addition to its use of GIS in its operations, MMD makes mining information available to the public through its website. The EMNRD MMD Coal Mine WebMap, which is powered by ArcGIS for Server and built using Microsoft Silverlight, shows the locations of active and inactive mines, coal mine permit boundaries, coal districts in New Mexico, soil type data, geologic period layers, and US coalfields characterized by coal type.

Santa Rita, New Mexico, in 1919 with copper mine in the background.

From Open Data to Data Engagement

By Bern Szukalski, Chief Technology Advocate

Beyond transparency and accountability, the ultimate goal of open government is to empower citizens by providing them with data in a meaningful context.

The principles of open government and transparency suggest public access to information leads to scrutiny. Public scrutiny ultimately leads to accountability. Transparency and accountability together empower a public audience to weigh in on issues that matter to them, and provide an opportunity to influence decisions and hold the people making those decisions accountable.

When it comes to opening up GIS data, transparency is often cited as being a key driving factor in making that data available. But simply providing downloads for data is not enough—and in the grand scope of openness is somewhat meaningless.

Opening up GIS data is not an end but rather a means to enable appropriate decisions, scrutiny, input, and also innovation. This requires more than just a one-time cul-de-sac data download. It requires a connection to the source and context that make that data inherently more meaningful, and subsequently more powerful. Our challenge is to think beyond the data download, and expand our thinking about what open data means in the modern context of web GIS.

Why Should GIS Data Be Open?

Beyond the drivers that openness and transparency is not only a good idea, but a required checkbox in today's government landscape, there are many reasons why opening up GIS data makes a lot of sense. It supports innovation and entrepreneurship. It facilitates communication and response, and supports better decisions. It bring together a broader community that can also contribute and participate. But looking inward, there are advantages as well. Breaking down internal information silos and amplifying the value of your GIS investments are but two.

Thinking Beyond the Download

In today's web GIS world, open data needs to be far more than a website that offers shapefile, spreadsheet, or KML downloads. It needs to be a way that others can engage over GIS content. That content must be curated and authoritative, updated and timely. But more importantly it must be actionable—presented in ways that make sense to the user, and that enable engagement using the data.

The potential users of your open data are many—public consumers, knowledge workers in other organizations, and developers and entrepreneurs. With a broad landscape of potential users and uses, it's vital to think beyond the download, and consider "openness" in the context of other delivery mechanisms to serve engagement.

Many Ways to Connect People with Data

Engagement can come in a variety of forms. It can be as simple as a spreadsheet or shapefile download, but that should not be a one-way street. That download should, at a minimum, include a way to subscribe to the source to learn of updates or changes once the data has been fetched.

Alternatively, that same data can also be offered as services that can be connected to directly from the source where it is maintained and updated. This is a far better approach and one that leverages and supports the web GIS ecosystem.

Building applications and information products—including Esri Story Maps—is also a way of opening up your data for engagement. While not traditionally thought of as open data, these are valuable ways not just to open your data, but more importantly, to present information in a meaningful context that will engage a broader audience.

A portal is now an inherent part of a web GIS. It serves as the central clearinghouse for engagement within your organization, to developers and entrepreneurs, and to a broader audience. It's a relatively new but very powerful part of the ArcGIS platform. ArcGIS Open Data is another type of configurable portal that is part of your GIS organization that leverages some of the same resources in your portal to enable their use by a different audience.

Engagement, Not Openness, Is the Goal

The idea of providing open access to data in a way that engages the public is rapidly changing from something that would be nice to have to an essential element for success. The ArcGIS platform provides many opportunities to open up your data, and engage others. These include downloads, access to services, configurable apps and story maps, and all are facilitated and managed via your portal.

Regardless of which options you choose, the goal is not just to open up your data but to offer ways to interact with it, experience it, and amplify the inherent value of your work by delivering opportunities for engagement.

About the Author

As the chief technology advocate and product strategist at Esri, **Bern Szukalski** is focusing on ways to broaden access to geographic information and helping users succeed with the ArcGIS Platform. Follow him on Twitter at @bernszukalski.

The ROI Mind-Set for GIS Managers

By Wade Kloos, State of Utah, Department of Natural Resources

At a GIS user group last year, the audience of 150 GIS professionals was asked, "How many of you measure your GIS results?" Not one person in the room raised a hand. This got me thinking. What does it take to get GIS professionals to think differently about measuring GIS return on investment (ROI)?

This article will explore why measuring ROI can help your GIS program and how your mind-set is fundamental to your journey to something better for your program.

Studying ROI is a means to an end. In this case, the end is the measurement, documentation, and communication of the value of GIS. Knowing why ROI is important to you, a GIS manager, is a critical first step on the journey from a good GIS program to a great GIS program, so let's get started.

Chances are you will find yourself needing to justify a GIS project or a request for funding or respond to a threat to your existing resources. Even if you are so fortunate that you are never in this position, it is likely your organization's leadership currently undervalues the contribution of GIS. What would you reference as a measure of your GIS value? How do you think that measurement will resonate with your leadership? By addressing questions like these before your boss asks them, you are choosing the path from good to great. This is definitely worth your time.

GIS managers who prepare themselves for a discussion of GIS value are in a much better position to not only get what they want, but—by communicating the value of GIS value—can preempt internal threats that could diminish future GIS opportunities. Organizational leaders can be fickle, so they should be reminded of your program's contributions on a regular basis.

Having repeatable metrics and dedicated ROI workflows can help your program remain relevant. This relevancy can keep leadership's attention focused on how GIS impacts its business, not just on the maps you make. In addition, the value you assign to GIS results should be closely linked to the way your organization—as a whole—measures value. For example, if your company focuses on dollars earned as a measure of success, your GIS results would be better understood and appreciated if they relate to that success measure by highlighting increased revenue, cost reduction/avoidance, efficiencies, and other dollar benefits.

So how does the concept of mind-set fit with ROI, and how does one define and/or change a mind-set? Have you ever had one of those days at work in which everything you set out to do gets pushed to the side so that you can keep your GIS program running, your staff on task, and your deliverables on schedule?

Perhaps that day turned into a week and then a month so fast it made you wonder where all that time went and what actually got done. I don't think it is a stretch to suggest that the stresses and workloads you face as a GIS manager can be all-consuming, occupying your thoughts and time while at work (and beyond). This kind of environment can influence your mind-set.

To reinforce the importance of recognizing my thoughts, attitudes, and actions in a busy work environment, I turn to *The 4 Disciplines of Execution* by Chris McChesney, Sean Covey, and Jim Huling. The authors introduce the concept of the "whirlwind" of work. They claim that the whirlwind is the one thing that most prevents us from achieving our goals. The whirlwind of GIS activities needed just to keep the operation running day to day and serving the ad hoc needs (usually labled "urgent") of the organization can consume massive amounts of energy.

Being reactionary, multitasking, reprioritizing, and temporarily focusing on tasks of little consequence can leave your mind spinning and full of limitations and negative perceptions. When you think about ROI efforts in the midst of this whirlwind, you may conclude that

- You are too busy pleasing everyone else to work on GIS ROI.
- You are not being asked for ROI, so you are not doing it.
- Your budget has been steady, so ROI doesn't seem relevant.
- Your program may not be as good as other GIS programs, so you don't want to find out by measuring it.
- ROI studies consume too much time and are just for big projects.
- You don't do ROI because you are not sure how to do it.

These conclusions may be preventing you from exploring the value of your GIS and its ROI. They may be preventing you from taking a path to something better. Such thoughts frame one's mind-set. In her book entitled *Mindset; The New Psychology of Success*, Carol Dweck would term those thoughts as examples of a "fixed" mind-set. Persons with a fixed mind-set let judgments, fear, and the abilities they currently possess frame how they interpret situations and opportunities.

This fixed mind-set is the opposite of the "growth" mind-set. The general outlook of persons with a growth mind-set is shaped by a process of continuous learning. Because they are willing to try new things (even if they may fail), they do not accept that what they currently know or what their current situation is defines their future. Further, they believe that through learning—even if it is learning from their mistakes—they can improve their situation so that greater things are within their grasp. Adopting a growth mind-set can really help your GIS program succeed.

How does one define GIS success? Answering this question is one way to begin *learning* what is applicable and relevant to your situation and organization. A key factor in determining the success of a GIS program is to first appreciate the fact that GIS exists in your organization specifically to help your organization reach its goals or achieve its mission.

GIS is a business support system. It does not solely exist for the purpose of creating a digital representation of the world. With this in mind, the next logical question is, "What difference does your GIS make in reaching organizational goals?"

To answer this question, you will need to immerse yourself in the business functions of your organization, many of which may be subjects with which you are not familiar. This is where having a growth mind-set will benefit your GIS program. The more institutional knowledge of the business and information challenges and opportunities you acquire, the more clarity you will have about the potential difference GIS can make and its relevance to your organization.

Running a GIS program is already a challenging, time-consuming task, so is it any wonder that becoming intimately familiar with numerous organizational business units is not a top priority for you? But if you accept this premise, you have a fixed mind-set.

Can you begin to see that the more integrated your GIS is with business functions, the more relevant GIS will be and the greater its and your value will be to the organization? Think business-centric solutions and not map-centric solutions.

If you never leave your GIS cubicle, you'll have difficulty establishing the relevance of your GIS program to your employers. A GIS manager's time is in high demand. However, the time you dedicate to organizational learning, as well as measuring and communicating GIS results, will get you precious resources and your leadership's attention and appreciation.

Cultivating a growth mind-set that is focused on ROI will crystalize your understanding of where and how GIS can make the biggest impact and—in the process—get your organization closer to achieving its mission and goals. Isn't that the real measure of GIS success?

Take a Closer Look at Your GIS

By Bill Meehan, Esri Utility Solutions Director

Are you getting everything you can from your GIS?

How do you know? It might be time for a little introspection. Although this article focuses on GIS managers in the utilities industry, you can apply the thinking behind these questions to your organization no matter what you do. You will likely discover areas where you can expand the use of GIS throughout your organization and maximize its (and your) value.

Seems everyone takes selfies these days with their smartphones, posting pictures of themselves on Facebook, Twitter, or other social media. This seems awfully self-indulgent. Yet maybe it's a good thing to take a hard look at yourself once in a while. Maybe taking a selfie gives you a chance to reinvent yourself.

Likewise, utilities and other organizations need to reassess their practices, particularly in this age of rapid change that touches on everything from climate and renewable resources to technology. One technology that utilities might want to take a hard look at is their GIS. After all, utilities have been using GIS for ages, so it's probably time to modernize. Here are seven ways utilities can modernize their GIS:

1 Take a selfie of your GIS.

Now's the time to ask yourself, is my GIS doing what I want it to? Is my GIS just a technology to computerize my old operating maps faster and make them neater? Here's a question for you: Are you still printing those old maps and mailing them to district offices? Maybe you create a PDF and email it instead. But if that's the case, are you at least also leveraging the latest technology, such as the cloud, imagery, smartphones, and tablets? Could your editing process be streamlined? Based on your answers, it might be time to change things—and fast.

2 Use GIS to solve business—not just mapping—problems.

Most utilities still use GIS only in operations and perhaps for a few workflows like outage management or distribution design. But think about how many of your problems relate to location. What if you could find where workers are more likely to get hurt? Or imagine you could map Tweets of unhappy customers. Your GIS could even pull crime statistics from the police department's GIS and layer these on top of streetlight outages. That could help to prepare your field crews.

3 Stop thinking about GIS as an application; it's a platform.

In the past, GIS was a client/server system, and it was hard to integrate it with other systems. But today, GIS talks easily to other business systems. It's a platform meant to be integrated. Business systems need location, and they get that today not by using clunky processes for extract, transfer, and load but rather by collaborating directly with the GIS. Modern GIS rethinks and simplifies the whole information technology architecture. GIS draws on fast, secure web services to leverage the wealth of data available from the web—whether the information was collected around the corner from you or around the world.

4 Stop building custom GIS applications.

Most people don't know that GIS is about configuration, not customization. Spatial and location analytics comes out of the box. Today you can find templates and third-party providers for nearly any workflow. And if not, it's pretty easy to create your own workflow with built-in configuration tools that come standard with the GIS. Esri pays special attention to making sure you can do that within ArcGIS. *[Visit solutions.arcgis.com to download free templates for ArcGIS.]*

5 Simplify your asset data model.

Most data models are too complicated. One of my colleagues likes to describe this old-fashioned GIS as being like a blueberry muffin with too many blueberries—it's too heavy. Every time a utility builds a new application, more blueberries are added. The cleanest system has the least amount of blueberries, or attribute data, in the model. Don't duplicate data; it should exist in only one system. If you need the data in an application, reference it from somewhere else. Just because you want to display data in your GIS doesn't mean it has to be stored there. Remember this: simplicity scales; complexity fails.

6 Stop building your own basemaps.

In the early days of digital mapping, utilities built their own basemaps with relevant streets, landmarks, parcels, and water bodies. But these old maps had no accurate coordinate system; they mostly predated GPS and will never be as accurate. There are many accurate basemaps Esri makes available online for free from Esri's Living Atlas of the World hosted on ArcGIS Online. Use them. Sure, you will have to adjust your asset information, but in the end having a more accurate coordinate system will save you lots of time and aggravation. Plus, you won't have to store, manage, or edit that data ever again. If you need to access data about a proposed street plan, find and store it in the GIS as a separate layer. Once it's in your basemap, you can place it anywhere.

7 Fix your data.

If your data stinks, so does your GIS. Despite knowing this, utilities still encounter bad data plaguing their industry. With incorrect, incomplete, or old data, GIS features and functions are useless. With all the effort you put into building a sophisticated data model, don't short sell it by populating it with bad data.

So take a selfie of your GIS, study it, and then take these steps to modernize your GIS.

About the Author

Bill Meehan is the director of Esri utility solutions and a registered professional engineer. Meehan is the author of *Empowering Electric and Gas Utilities with GIS*, *Power System Analysis by Digital Computer*, *Modeling Electric Distribution with GIS*, and *GIS for Enhanced Electric Utility Performance*, as well as numerous papers and articles, and has lectured extensively and taught courses at Northeastern University and the University of Massachusetts. Prior to joining Esri, Meehan was the vice president of Electric Operations at NSTAR, an electric and gas utility in Boston. He holds a bachelor's degree in electrical engineering from Northeastern University and a master's degree in electric power engineering from Rensselaer Polytechnic Institute.

Create Beautiful Infographics

with ArcGIS Runtime SDK for Qt and Qt Charts

By Lucas Danzinger, Esri Product Development

One of the great things about Esri's ArcGIS Runtime SDK for Qt is that it provides an API that seamlessly plugs into a rich framework that is platform agnostic and has nearly endless possibilities.

This allows you to bring the power of location and ArcGIS into larger projects that take full advantage of the framework and its multitude of APIs and plug-ins. One of my favorite modules from the Qt Framework is Qt Charts, which is an enterprise add-in that allows you to easily create visually appealing charts and graphs. These charts and graphs, coupled with beautifully designed maps from ArcGIS, allow you to create data exploration tools and infographics that are extremely valuable when trying to tell a story about your data.

As an example, I created a data exploration tool for Los Angeles County. I wanted to explore how demographics, crime rates, and income were related in the Los Angeles area. To do this, I used block group-level demographic data from the US Census available from Data and Maps for ArcGIS along with some crime data for 30 days in CSV format from the Los Angeles County Sheriff's Department. Using analysis tools in ArcMap, I was able to quickly aggregate the data by block group and publish it as a feature service to ArcGIS Online.

Now to the fun part—writing code! I envisioned my app as an interactive tool for users to explore the map and obtain summarized data as they navigated to new areas of the map. To do this, the user clicks on the map, and a buffer around that point is created using the geometry engine that is built into the Runtime API.

This buffer acts as a cookie cutter. All the demographic and crime data for blocks that intersect with the buffer is summarized quickly and represented on the graphs.

The coding was straightforward and revolved largely around executing Query Tasks against the Feature Service, then feeding the results to the different elements in the charts. Query Tasks takes advantage of a concept called Out Statistics, which allows you to specify a field and a statistic type. Instead of returning all the features inside your input geometry, Out Statistics will return one feature with all your summarized statistics. Listing 2 is an example of the code to do this written in QML.

Once the Query task completes, the code in Listing 3 causes the data to be fed into some bar and pie charts for easy data visualization.

Finally, all this is overlaid on an Esri-provided Median Household Income dynamic map service. I chose this specific dynamic map so the user can see trends and correlations between the demographic, income, and crime-related data.

This project, called QML Maps and Charts, can be found on ArcGIS Online. Feel free to download the source code and explore the application on your own. If you're interested in ArcGIS Runtime SDK for Qt and haven't already downloaded it and started developing, visit ArcGIS Runtime SDK for Qt (developers.arcgis.com/qt/) or ArcGIS Runtime SDK for Qt on GeoNet to learn more.

```
onMouseClicked: {
    // create the buffer
    gl.removeAllGraphics();
    var pt = mouse.mapPoint;
    var graphic = ArcGISRuntime.createObject("Graphic");
    var buffer = pt.buffer(5, mile);
    graphic.geometry = buffer;
    graphic.symbol = baseSFS;
    gl.addGraphic(graphic);

    // query features within the buffer
    demoQuery.geometry = buffer;
    demoQueryTask.execute(demoQuery)
}
```

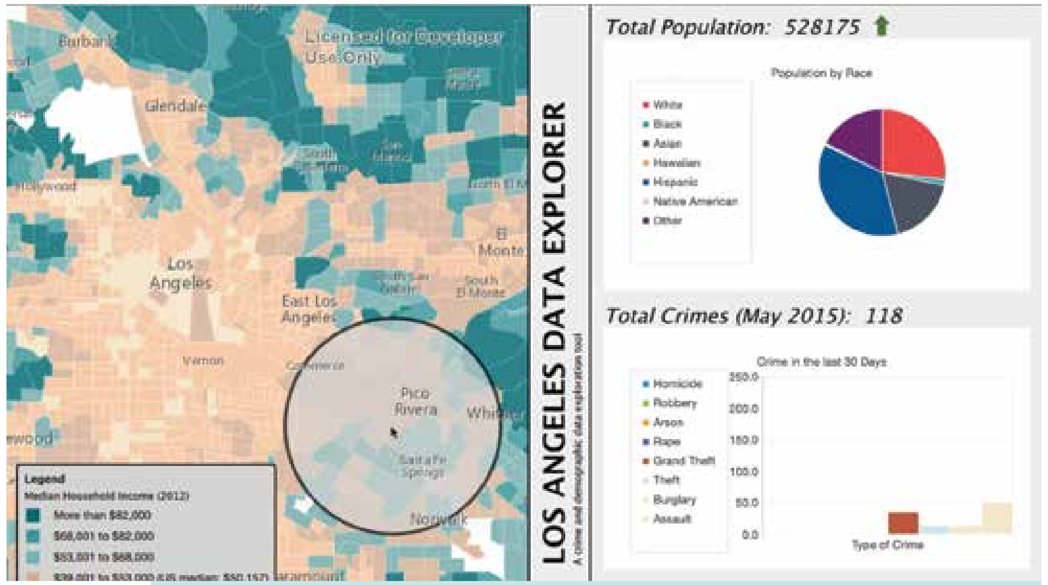
Listing 1: QML code for listening for a mouse click and creating the buffer and graphic

```
Query {
    id: demoQuery
    where: "1=1"
    spatialRelationship: Enums.SpatialRelationshipIntersects
    outSpatialReference: map.spatialReference
    outStatistics: [
        OutStatistics {
            statisticsType: Enums.StatisticsTypeSum
            onStatisticField: "POP2012"
            outStatisticFieldName: "TotalPop2012"
        },
        OutStatistics {
            statisticsType: Enums.StatisticsTypeSum
            onStatisticField: "POP2010"
            outStatisticFieldName: "TotalPop2010"
        },
```

Listing 2: QML code for using Query Tasks

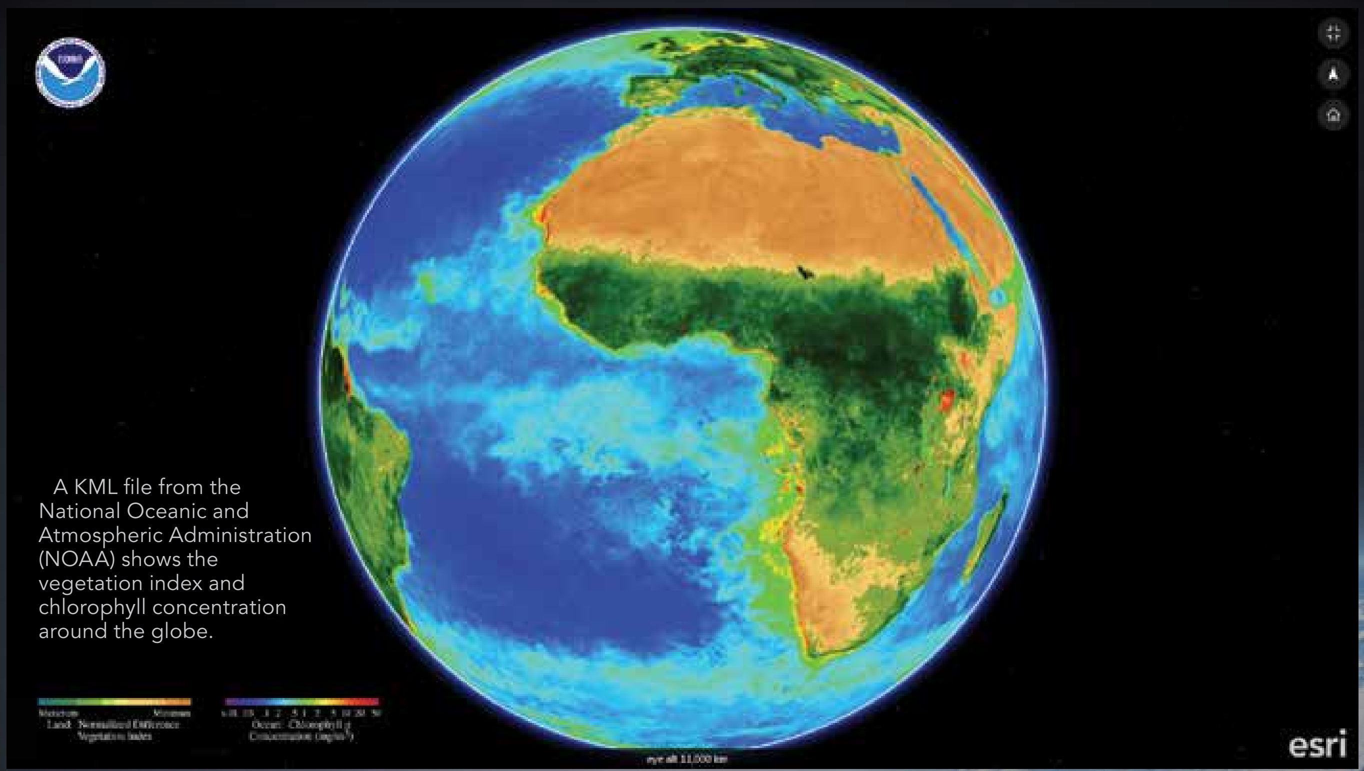
```
ChartView {
    id: barChart
    title: "Crime in the last 30 Days"
    anchors.fill: parent
    legend {
        alignment: Qt.AlignLeft
        backgroundVisible: true
    }
    antialiasing: true
    animationOptions: ChartView.AllAnimations

    BarSeries {
        axisX: BarCategoryAxis { categories: ["Type of Crime"] }
        BarSet { label: "Homicide"; values: totalCrime === 0 ? [1] : [criminalHomicide]; }
        BarSet { label: "Robbery"; values: totalCrime === 0 ? [1] : [robbery]; }
        BarSet { label: "Arson"; values: totalCrime === 0 ? [1] : [arson]; }
```

Listing 3: Feeding data into bar and pie charts



This data exploration tool summarizes all demographic and crime data for census blocks that intersect a buffer and represents that data in graphs.

Give ArcGIS Earth a Spin



A KML file from the National Oceanic and Atmospheric Administration (NOAA) shows the vegetation index and chlorophyll concentration around the globe.

ArcGIS Earth is a free, interactive globe for easily exploring the world and working with 2D and 3D data including KML and ArcGIS services. This lightweight, easy-to-use 64-bit Windows app for desktop is fully integrated with the ArcGIS platform and works with data stored in ArcGIS for Server and on ArcGIS Online, allowing secure access, sharing, and publishing of enterprise maps and data.

ArcGIS Earth complements existing 3D capabilities on the ArcGIS platform. Those capabilities range from advanced 2D and 3D visualization, editing, analysis, and publishing in ArcGIS Pro to viewing and sharing location information in 3D using just the 3D Scene Viewer and a web browser. ArcGIS Earth is part of Esri's offering for Google customers and partners looking to transition to Esri software. Along with other capabilities of the ArcGIS platform, ArcGIS Earth provides an alternative to Google Earth Enterprise Client. Developers with a Google Apps API key can implement Google Street View inside ArcGIS Earth by using a web service, calling a Google Street View in KML, and pointing ArcGIS Earth to that service to display Google Street Views.

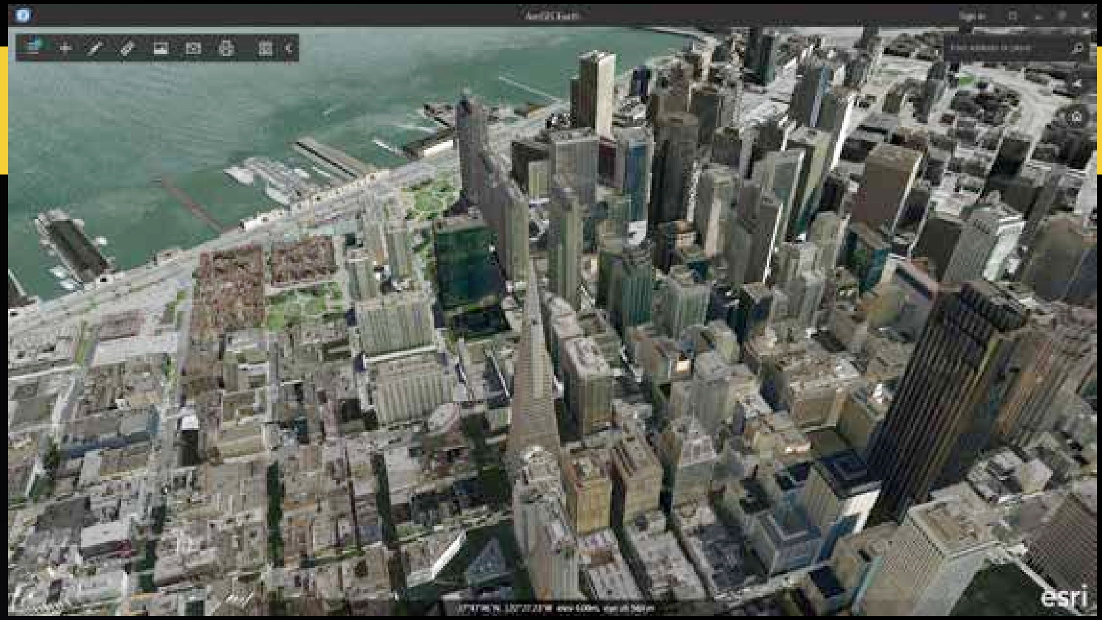
It has strong support for KML workflows. Add KML and KMZ data, including georeferenced COLLADA files, KML files with network links, and the KML data containing features and imagery that is available from government websites. You can access map data that has been shared as a file or as a link.

ArcGIS Earth can use publicly shared feature, scene, map, and image services through a URL or by browsing and discovering services in an instance of Portal for ArcGIS or in ArcGIS Online. Combine file and services data with publicly shared basemaps from ArcGIS Online, including global imagery, topographic maps, world ocean maps, and OpenStreetMap. Access and display demographic, landscape, terrain, and transportation data from the Living Atlas of the World. Logging in to ArcGIS Online with a named user account will give you access to secured and privately shared data in Organizations and Groups and any premium content associated with the account.

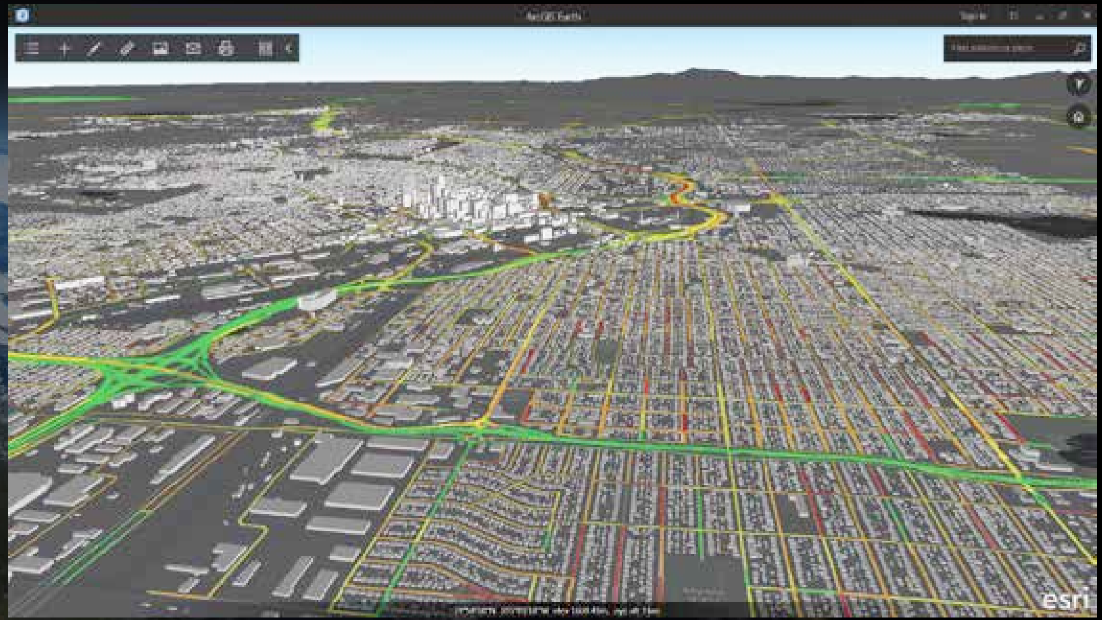
One of the main goals for ArcGIS Earth is to let you quickly share data and collaborate with other users. Functionality for capturing and emailing screen shots with a single click is built into the interface. You can double-click KML attachments in an email to open ArcGIS Earth and immediately visualize the KML data. Drag shapefiles from a shared network drive into the ArcGIS Earth view, and they will open and be added to the table of contents. The user interface has been intentionally minimized to maximize your view of the data.

Users can interact with data quickly and easily to understand the full picture. Basic linear, radial, and segmented distance measurements can be made to understand elevation and measure distance and area. You can draw point, line, or polygon place marks and add annotations with easy-to-use tools.

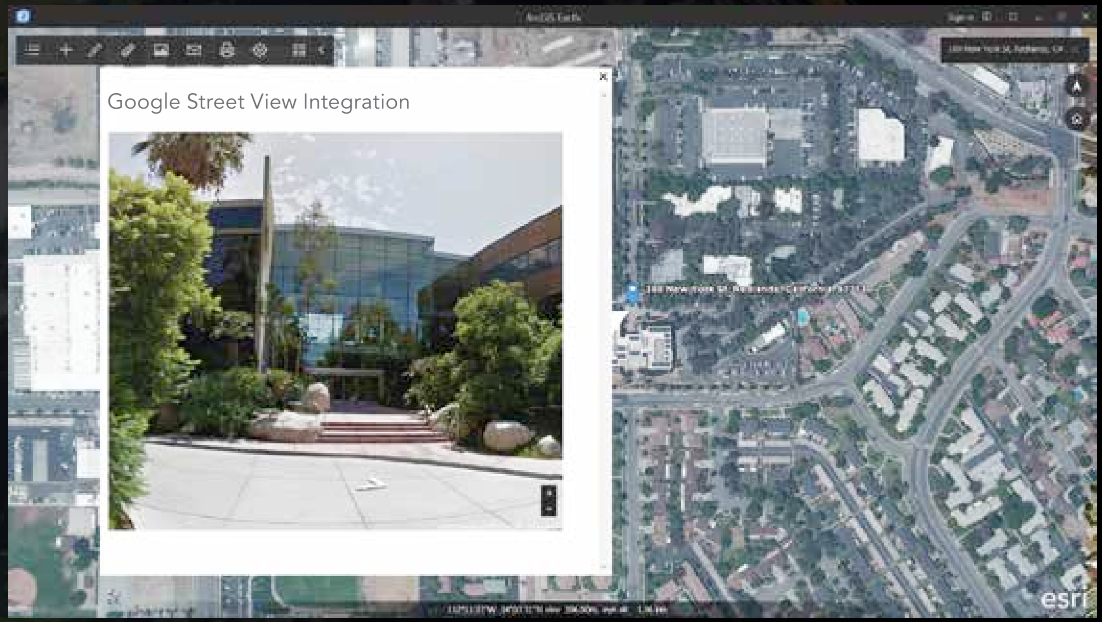
Integrate 3D into your workflows by downloading and installing ArcGIS Earth for free from esri.com/earth. Future releases of ArcGIS Earth will add support for Web Map Service (WMS) time sliders, map tours, and offline use.



3D scene layer in ArcGIS Earth showing realistic Pictometry buildings



World Traffic Service in ArcGIS Earth showing near real-time traffic information



Developers with a Google Apps API key can implement Google Street View inside ArcGIS Earth.

Re-creating Part of Richmond's Past

By Justin Madron, University of Richmond

Eyre Crowe, an English painter who arrived in Richmond in March 1853, witnessed several slave auctions and recorded what he saw in his powerful painting *Slaves Waiting for Sale*.

Eyre Crowe, an English painter who was accompanying British novelist William Thackeray on a lecture tour of the United States, arrived in Richmond, Virginia, in March 1853. On Crowe's first full day in the city, he set out for an area of the city called Shockoe Bottom to witness several slave auctions, hoping to find "a possibly dramatic subject for pictorial illustration." Crowe recorded what he saw in his powerful painting *Slaves Waiting for Sale*.

Fast-forward more than 150 years. Many people are still seeking a greater understanding of the subject of Crowe's painting, the slave trade. Most of the sites where people were bought and sold in Richmond have been obscured by development. The Digital Scholarship Lab (DSL) at the University of Richmond has reconstructed this historic landscape in a 3D visualization for an exhibit at the Library of Virginia, "To Be Sold—Virginia and the American Slave Trade," that was on display from October 2014 to May 2015. An online version of the exhibit can currently be viewed at www.virginiamemory.com/online-exhibitions/exhibits/show/to-be-sold.

The goal of building the 3D visualization was to help visitors envision Crowe's journey through Richmond and experience the slave trade through his paintings and engravings. This was a challenge for a number of reasons. One was the lack of evidence of the built environment of the city in the early 1850s. Building footprints—the foundation of any urban 3D model—were nonexistent for that time period. DSL opted to use an 1876 map by F. W. Beers that showed buildings, parks, and other features in great detail.

To minimize the problems with using an 1876 map to represent Richmond in 1853, DSL georeferenced other maps of Richmond from the 1850s using the Georeferencing toolbar in ArcMap. With this combination of maps, DSL digitized more than 3,000 building footprints in ArcMap that were based on the F. W. Beers map. DSL staff, with help from Dr. Maurie McInnis, the curator of the exhibit and author of a recent study of the visual and material culture of the American slave trade, gathered numerous photos of buildings and detailed descriptions of the materials and architectural styles of the city during the 1850s.

To reconstruct the Richmond Crowe saw in 1853, the Digital Scholarship Lab employed Esri CityEngine to quickly generate the bulk of the city's 3,000 buildings using footprints and information on the general building materials and architectural styles used at that time.

The red buildings indicate the locations of slave auction houses, jails, and hotels. The locations of these buildings have been obscured by the construction of new buildings and Interstate 95.

Accurately modeling thousands of buildings to portray antebellum Richmond was no small task. DSL student interns started modeling buildings by hand, using photographs and footprints exported from ArcMap into Google SketchUp. These buildings were highly detailed, but it took more than four months to produce 30 buildings.

With over 3,000 buildings left to model and a majority of them lacking pictorial evidence, the project was off to a slow start. The only information for most of these buildings was the general building materials used and the architectural styles employed.

"Esri CityEngine solved an enormous problem for us," said Nathaniel Ayers, the visualization and web designer at the DSL. CityEngine perfectly met the challenge of modeling a large-scale 3D urban environment. Its procedural modeling approach enabled DSL to generate a large number of buildings that were true to the architectural style of historic Richmond. Using a set of rules based on information such as building height, window spacing, and facade textures, the procedural content was generated in a matter of seconds versus the months it would have taken with a traditional hand-modeling approach.

Since CityEngine uses shapefiles as input, uploading the building footprints was seamless. Tree point locations were also uploaded, and Esri's 3D Vegetation Library was used to generate trees for the model. The generated buildings and trees were exported as an OBJ file. The file was imported into 3D Studio Max 2013 for final rendering and animation to give the model consistency, since different software products were used to model buildings.

The project drew from multiple 3D modeling software applications. ArcMap was used for creating the building footprints for the model. CityEngine generated the bulk of the buildings. Using a combination of modeling approaches allowed DSL to capture the architectural details of a specific time and place and apply these styles over dozens of square blocks of a city. This gives viewers a real sense of what the city was like during this time. Using CityEngine's procedural modeling approach, along with more traditional modeling styles, resulted in a stunning visualization of what Richmond might have been like when Crowe experienced the slave trade and created his striking paintings and engravings.

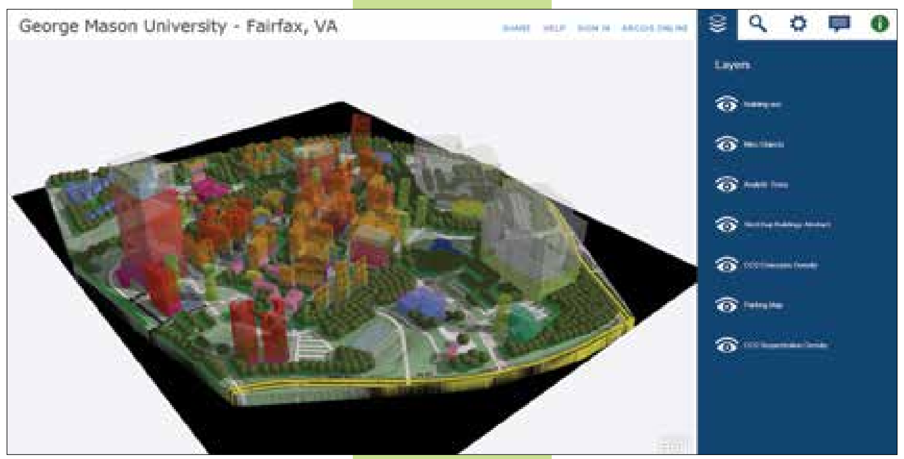
See a video of this project at dsl.richmond.edu/richmond3d/. For more information, contact Justin Madron, GIS analyst at the University of Richmond's Digital Scholarship Lab, at jmadron@richmond.edu.

Creating a 3D Campus Scene Using Esri CityEngine

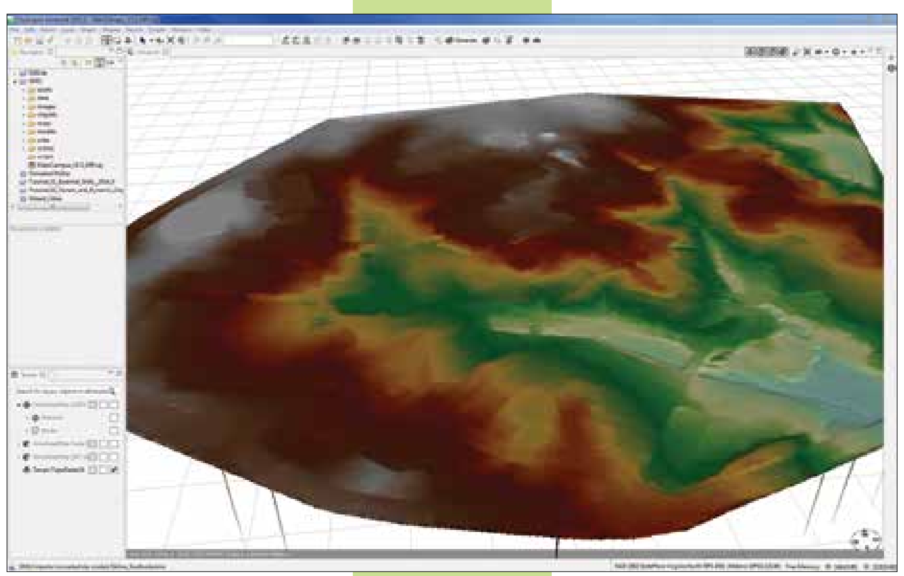
By Michael Piccione, Thomas Jefferson High School for Science and Technology, and
Sven Fuhrmann, George Mason University

This article describes the workflow used to create a 3D campus scene of George Mason University that can be displayed using CityEngine Web Scene. This workflow required ArcGIS for Desktop, the ArcGIS 3D Analyst extension, and Esri CityEngine.

The web scene was created by Zhihang (Steven) Li, Michael Rodriguez, and Alec Zhang, who are students at Thomas Jefferson High School for Science and Technology. They were working on a special project under the guidance of Dr. Sven Fuhrmann, associate professor of Geovisualization and Geoinformation Science (GGS) at George Mason University, and Michael Piccione, faculty at Thomas Jefferson working on a grant with the GGS department. The George Mason University campus web scene can be viewed at http://mygmu.maps.arcgis.com/apps/CEWebViewer/viewer.html?3dWebScene=704a4db6120344a884a3fa5f93067384.



The completed model of the George Mason University campus in the CityEngine Web Scene.



A TIN of the campus was imported into CityEngine.

Workflow Overview

The first step in the process was the generation of a campus elevation model. A labeled raster image file was created so it could be draped over the model. At this point, 3D roads and sidewalks were generated and imported into Esri CityEngine. Finally, buildings were either imported or created, trees imported or generated, and thematic data symbolized.

Importing a TIN File into CityEngine

A triangular irregular network (TIN) file represents a surface and is often used to visualize terrain information. A TIN was used for the base elevation data for the campus area, but several other elevation data options would also have worked. A TIN for Fairfax County was acquired and clipped to the area of George Mason University.

To prepare the TIN for CityEngine, it was opened in ArcMap, and the TIN To Raster tool (in the 3D Analyst toolbox) was used to convert the TIN to a raster. The Sampling Distance option used should be a cell size of less than 10 meters, and 3 to 4 meters is preferable. After opening the output raster, it was exported as a TIFF to the CityEngine workspace. The TIFF was dragged into CityEngine as a terrain layer.

Creating an Overlay Image

Once the elevation model is generated, it is usually draped over with an air photo. CityEngine supports image overlays on terrain data. It is advisable to make all edits to the image before draping it on the terrain.

In this case, OpenStreetMap (OSM) was used as a basis to develop an overlay image. OSM provides a suitable basis to create an abstract representation of the general infrastructure on university campus, but other image overlay options exist. OSM data matching the extent of the elevation model was exported and converted to an image file with Maperitive 2.0, a free desktop application for drawing maps based on OpenStreetMap and GPS data, and exported as a BMP file at the preferred scale. More than one image can serve as background in CityEngine's Web Scene if text or other features need to be adjusted for various zoom levels or for visibility reasons.

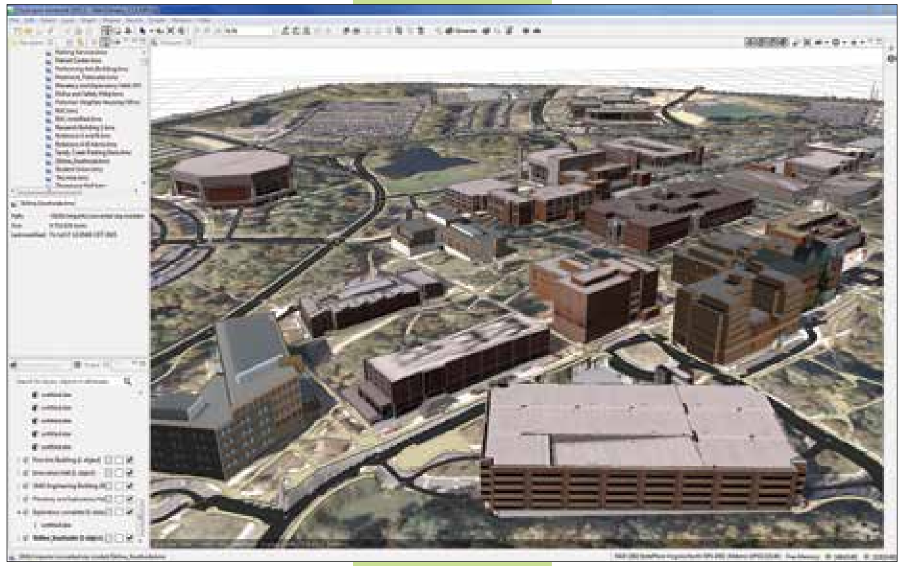
Trimmed OSM image with x,y control points marked after georeferencing

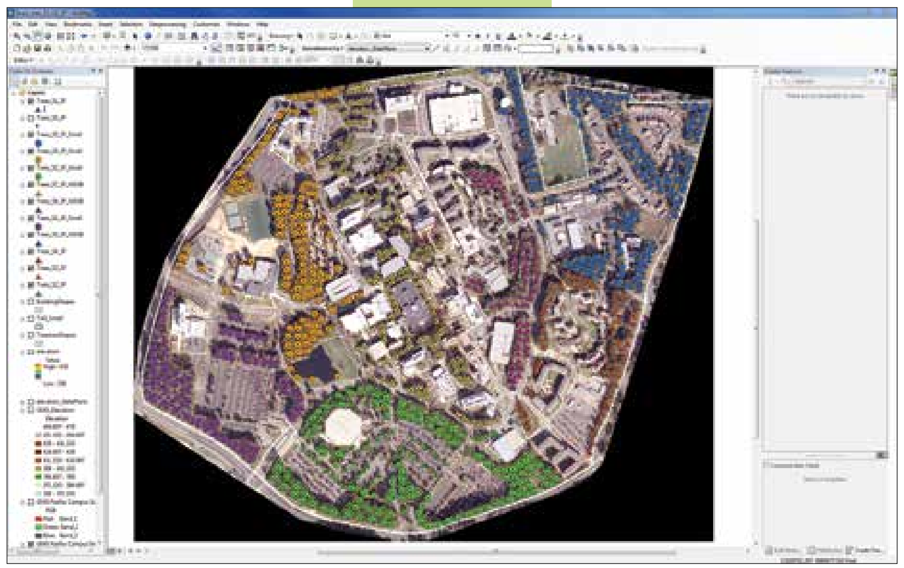
Geolocated buildings were created in SketchUp using camera images with the Match Picture feature.

Overlaying the Georeferenced Raster

To overlay a raster image over the target area, it may need to be georeferenced in ArcGIS first if it doesn't import correctly into CityEngine. To georeference the raster dataset in ArcGIS, multiple sets of x- and z-coordinates of OSM vertices around the perimeter of the area (such as road intersections) that are common to both the raster and aligned dataset and easily identified were located and recorded.

In ArcGIS, the Georeferencing toolbar was used to place control points first on the raster image and then at the x- and y-target coordinates taken from the OSM data. Depending on the number of points to be georeferenced, first- or second-degree transformation can be used to stretch or bend the raster dataset to better match the target. After the transformation was selected, georeferencing was updated.





Imported models and CityEngine models on an OSM satellite image in CityEngine

Tree point dataset created in ArcMap

Clip the Georeferenced Image

A polygon was created in CityEngine that traced the border of the terrain file. A polyline could also have been used. The x,y coordinates of the polygon nodes were recorded. In ArcMap, the georeferenced image was opened and a polygon drawn using the same coordinates as the border traced in CityEngine. The image was exported with the Using Selected Graphics option so only the image contained within the polygon was exported. This clipped raster file was imported into CityEngine and used as a texture overlay for the terrain.

Importing 3D Models

In the campus model, roads and sidewalks could have been created as 3D objects in CityEngine so that they would not be positioned below the terrain. Any kind of 3D object can be imported from various CAD packages or Trimble SketchUp 2015. SketchUp 3D Warehouse (3dwarehouse.sketchup.com) is an excellent source of SketchUp models. For the web scene, several campus buildings that had been previously created were downloaded from 3D Warehouse.

The buildings that were not available in 3D Warehouse were created by team members in SketchUp. The Match Picture feature was used while importing building pictures to draw the building geometries based on photographs. Selected models were imported into SketchUp. In SketchUp, the Georeference tool was used to georeference the file on the map close to the location it would be placed in CityEngine and exported as a KMZ file.

Import Objects into CityEngine

Exported SketchUp and CAD files were moved to a folder in the CityEngine workspace. In CityEngine, the files were imported into the scene as KMZ or DXF files or dragged from the folder in the left browser menu area onto the scene.

If files in the scene didn't line up correctly, they were moved or copied to the correct location. To reduce the file size and complexity and enable editing of the files using rules, they were converted to shapes using Convert Model To Shape tool in CityEngine. The Clean Up Shape tool was used to simplify the number of vertices.

The problems encountered were related to georeferencing and file size. If the file isn't georeferenced correctly, it may not import correctly because its coordinates exist outside the extent of the web scene. KMZ files cannot be imported into a scene unless they are georeferenced in the current workspace. Pay attention to the file size. Many models are very detailed and use several megabytes of memory. Importing too many objects into the scene may cause CityEngine to crash.

Creating Buildings in CityEngine

Detailed building models that did not exist were created using rules in CityEngine and building footprints from OSM. Generic shapes can be extruded from the building footprints and features edited by modifying the rendering rules. Generic buildings were generated to match common building styles on campus by using the extrude command (height) and then an appropriate roof command (roofHip, roofPyramid, etc.) and texture application. The texture argument was either a variable associated with a file or an actual file that was referenced. Buildings conform to the building footprint because only solid modeling features are used to extrude them. Most buildings in the scene were imported, but some were created using OSM footprints and facade patterns that were similar to other buildings on campus.

Adding Trees and Vegetation

After placing the buildings, the next process was populating the web scene with trees and vegetation. There are many different ways to do this, but the two methods used were importing trees from the SketchUp 3D Warehouse and generating tree models from an ArcGIS tree point plot. Some 2D trees replaced modeled trees because the scene redraw lagged due to the overall number of trees. Users preferred 2D trees when viewing the artistic rendering but preferred 3D trees in the realistic view.

When only a few trees are needed or when the ideal tree model is not available from the Esri Vegetation Library, obtaining them from the SketchUp 3D Warehouse works well. Desired tree and plant models were selected and imported from the 3D Warehouse into SketchUp. The Georeference tool was used to locate the models on the map close to where they would be placed in CityEngine and exported as KMZ files.

The exported files were moved to a folder in the CityEngine workspace. In CityEngine, the files were imported into the scene as KMZ files or dragged from the folder in the left browser menu area onto the scene. Once a file was in the scene, it was moved or copied by dragging it to the correct location. Tree models were aligned to the terrain using the Align Shapes To Terrain button and the Move tool when necessary. Copies of the tree and plant models were made and dragged to the proper locations.

Generating Tree Models from an ArcGIS Tree Point Dataset

If more than a few trees will be used to populate the web scene, generating tree models is more efficient. A new point shapefile was created in ArcCatalog and added to the map document in ArcMap. Using the Editor toolbar, points representing tree locations were added to the map, and the layer was exported as a shapefile.

The tree location shapefile was imported into CityEngine and the tree points aligned to the terrain. A rule file was assigned to the tree points to generate the trees and display them in CityEngine. A comprehensive CGA rule file called Essential_Plant_Loader.cga, containing around 100 different species of trees and three different tree model types, can be found at the Esri website.

Randomizing Tree Species

The tree pattern and species selection can be randomized using the plant rule file. The tree species that would be randomized were determined. The size of the set was established as the variable *n*. A field labeled SpeciesNum was created in the tree shapefile attribute table to store random species numbers. For each point, a random number from 0 to *n* was assigned. This process was expedited using Microsoft Excel and copying and pasting the resultant numbers

Academic, residential, and commercial building types were color-coded.

Listing 1: Function to randomly generate trees

```
_choose(SpeciesNum) =
   case SpeciesNum <= 1: "White Oak"
   case SpeciesNum <= 2: "Northern Red Oak"
   case SpeciesNum <= 3: "Sugar Maple"
   case SpeciesNum <= 4: "Black Locust"
   case SpeciesNum <= 5: "Ficus"
   else: "Alder Buckthorn"
```

Realistic trees placed on the campus model as dictated by a tree plot. The species distribution was achieved through randomization.

A wide-angle view of the campus model showing realistic trees and ground imagery

into the attribute table. The tree point shapefile containing the SpeciesNum field was exported and imported into CityEngine.

In the CGA file, a function to choose a random tree species based on the SpeciesNum value was created. The choosing species function was called in the naming function set(_plantName, _choose(SpeciesNum)). Tree models were generated using this CGA file so different tree species were dispersed throughout the web scene. Listing 1 shows an example of this function.

Displaying Web Scenes with Thematic Content

Although campus models often contain building and infrastructure information, thematic data is often not included. Several other datasets were available, so the team explored how to include thematic data. The initial work at GMU focused on building energy usage, building CO_2 emissions, and tree CO_2 absorptions to generate a representation on environmental impact of energy usage on campus. Building heights were extruded in CityEngine based on energy consumption, creating a thematic three-dimensional web scene. The vertical extrusion approach allows one to display a variety of thematic variables. The team explored the display of categorical and quantitative data.

Campus models don't need to be photorealistic in all use cases. Often, campus guests want to know the location and use of buildings. CityEngine offers rule files that assign colors for different building uses. While rule files can be written to set the colors of individual buildings, this process quickly becomes tedious with a larger dataset. Since GMU has more than 100 campus buildings, the process was optimized by assigning an extra attribute in ArcMap to the building footprint shape.

Applying color gradients is the technique of transitioning from one color to another based on attribute values. Changes in color gradients can be used to either emphasize specific numerical values or ordinal data. In this case, numerical data was normalized so a gradient could be applied to the normalized values. Numerical values were mapped to values from 0 to 1. The formula, xnormalized = (x - xmin) / (xmax - xmin), can be scaled differently based on preferences (e.g., linear, exponential/logarithmic scaling).

Conclusion

The completed campus model was exported to Esri CityEngine Web Scene format so it could be viewed on the web and used for further application and research projects.

Campus model viewed as a web scene

Several layers can be turned on and off in the web scene to create a desired realistic or abstract representation.

This project served as a research environment for conducting spatial analysis that would have been more difficult to do otherwise. Research projects that grew out of the model included simulating the impact of building renovation on shading and skylines, visual analysis of the CO_2 equilibriums on the GMU campus, and analyzing correlations between shuttle bus demands and parking occupancy. The web scene displays realistic buildings overlaid on the campus map. The layers showing building use by color, analytical trees, CO_2 emissions density, CO_2 sequestration density, and parking structures can be toggled on and off. This model will provide assistance to other research projects and may serve as an aid for decision making by the campus facilities and transportation departments.

About the Authors

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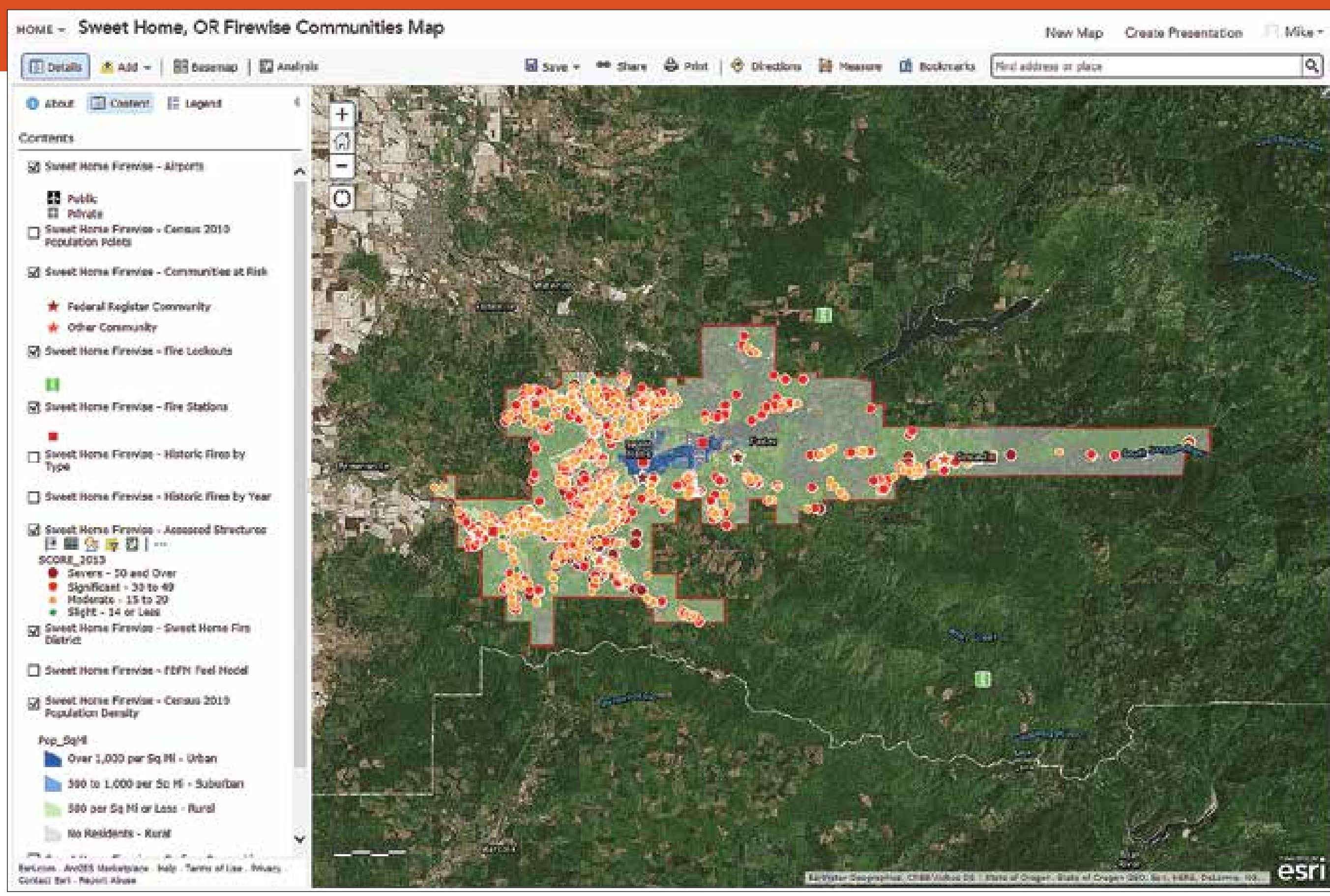
Using Web GIS to Build Consensus and Combat Wildland Fire Threats

By Mike Price, Entrada/San Juan, Inc.

What You Will Need

- ArcGIS 10.3 for Desktop (any license level)
- An ArcGIS Online account (one comes with your ArcGIS for Desktop)
- Sample dataset downloaded from esri.com/arcuser



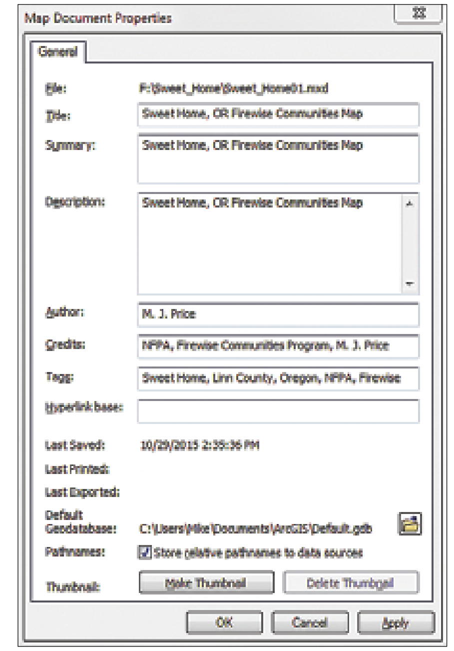
In this exercise, you share online a map showing community risk, hazard, and values for the Sweet Home Fire & Ambulance District, located in Linn County, Oregon.

Agencies and residents in areas at risk from wildland fires often develop a Community Wildfire Protection Plan (CWPP) to understand and mitigate wildland hazards and risk. This exercise shows how a map created in ArcMap that contains data used to develop a CWPP can be shared with the public and other agencies by generating a web map. This web map could also be used to gather input and gain support for various programs.

Concerned individuals collaborate with protection agencies, including firefighters, local and state government, and federal land management agencies, to produce a CWPP that identifies and measures the level of wildfire threat. Two important CWPP steps include conducting a community risk assessment and establishing community hazard reduction priorities. These steps are greatly enhanced and simplified using GIS for field data collection, analysis, and communication with shareholders. Developing a CWPP has never been easier with new tools and capabilities built into ArcGIS for Desktop and ArcGIS Online.

About This Exercise

In this exercise, you will review and share a map showing community risk, hazard, and values for the Sweet Home Fire & Ambulance District, located in Linn County, Oregon, approximately 80 miles south of Portland. Linn County stretches from the Willamette River valley eastward to the Cascade Crest, including the Interstate 5 corridor. Most Wildland/Urban Interface (WUI) communities are located east of Interstate 5 and include the towns of Lebanon and Sweet Home.



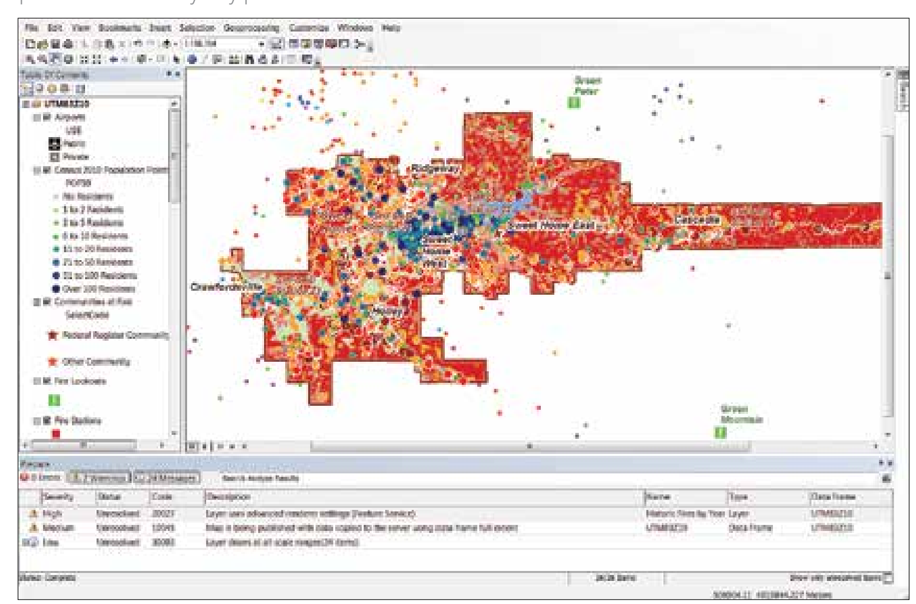
As soon as you open the map document, fill out its map properties.

From 2006 to 2008, Linn County, together with the Oregon Department of Forestry, the US Bureau of Land Management, the US Forest Service, and others, prepared a comprehensive Community Wildfire Protection Plan. Field data collection, community input, and WUI analyses were compiled and reported by ECONorthwest of Portland, Oregon, an economics, planning, and financial consulting services firm. Mapping was performed by my consulting GIS and geology mapping consulting firm, Entrada/San Juan, Inc., of Blaine, Washington.

The data for this exercise includes areas within the Sweet Home Fire & Ambulance District. The district's total area exceeds 145 square miles and includes the community of Sweet Home and extensive eastern forestlands. Through the Sweet Home Rural Fire Board, the agency provides protection to approximately 6,000 people and 2,500 structures in the district's 55-square-mile rural area. The data is synthesized to support valid field observations without compromising personal resident information.

This exercise opens with a finalized map of the Sweet Home District. After reviewing this map, you will make some changes to the map so that it can be published as a feature service on ArcGIS Online. After publishing the feature service, you will log on to ArcGIS Online, create a new map, and add the feature service. You will look at the data layers that are used in the analysis of risk, hazard, and value in an interactive map that can be shared internally and (if appropriate) externally.

Before sharing the map as a service, make some minor adjustments and run the Analyze process to identify any problems.



You will need an ArcGIS Online account to do this exercise. If you already have an organizational account, this exercise will consume a few credits. Even if it is not active, you will likely already have an ArcGIS Online subscription. You get an ArcGIS Online subscription with every ArcGIS for Desktop license that is current on maintenance. However, even if you do not have an ArcGIS Online subscription or ArcGIS for Desktop license, you can still do this exercise by signing up for a free 60-day trial for ArcGIS Online that provides access for five named users, all the ready-to-use apps, the Living Atlas of the World, and a 60-day trial of ArcGIS for Desktop.

Getting Started

To begin, visit the *ArcUser* website (esri.com/arcuser) and download the Sweet Home sample data. Save and unzip it on a local drive. In the Sweet_Home folder, open Sweet_Home01.mxd. To study the entire district, open Bookmarks and choose Sweet Home 1:200,000. Inspect the data layers and develop an understanding of the risk, hazard, value, and protection (RHVP) factors for this area. Layers that aid in the analysis of RHVP in the map include

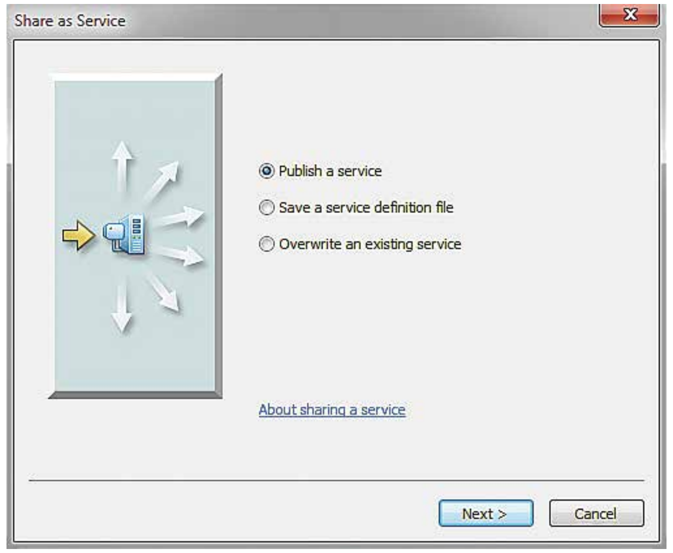
- Airports
- Census 2010 Population Points
- Communities at Risk
- Fire Lookouts
- Fire Stations
- Historic Fires by Type
- Historic Fires by Year
- Assessed Structures
- Sweet Home Fire District
- FBFM Fuel Model
- Census 2010 Population Density
- Surface Ownership

Preparing the Map for Publishing

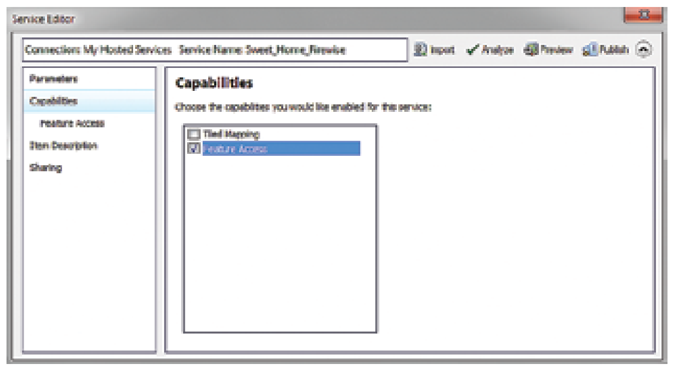
ArcGIS Online depends on robust metadata to support data loading, storage, and sharing. While the Sweet Home data includes complete metadata, the ArcMap document contains limited metadata.

The first step is to choose File > Map Document Properties to open the Map Document Properties window and provide initial metadata. Verify that the path to the file is correct.

Type Sweet Home, OR Firewise Communities Map for the title and copy this



In ArcGIS for Desktop, use the Service Editor to publish the map as a feature service hosted on ArcGIS Online.



Check Feature Access under Capabilities before unchecking Tiled Mapping.

title into the Summary and Description boxes.

Enter your name in the Author field. In the Credit field, type NFPA, Firewise Communities, and M. J. Price. (This data was obtained from multiple agencies; I simplified and synthesized it for this exercise.) For Tags, enter Sweet Home, Linn County, Oregon, NFPA, Firewise. Be sure to separate each tag with a comma.

Set the default Geodatabase to \Sweet_Home\GDBFiles\UTM83Z10\Sweet_Home.gdb. Check the box to use relative pathnames and create a thumbnail. Click Apply and save the project.

Signing in to ArcGIS Online, Ungrouping and Simplifying Symbology

In the Standard toolbar in ArcMap, choose File > Sign In. In the ArcGIS Sign In window, enter your user name and password and click SIGN IN.

After signing into ArcGIS Online, return to ArcGIS for Desktop to update several items in the table of contents (TOC) for Sweet_Home01.mxd. These changes will facilitate data publishing.

In the TOC, right-click the Historic Fires Group and choose Ungroup. ArcGIS Online does not allow grouped data, so these must be separate layers.

Next, right-click Historic Fires by Year, choose Properies, and click the Symbology tab. Click the Advanced button and open Symbol Levels. ArcGIS Online does not use symbol levels, but it will handle this issue when the feature service is created. Save the project.

Publishing Our Sweet Home Feature Service

Once again in the Standard toolbar in ArcMap, choose File > Share As > Service. In the Share as Service wizard, click the Publish a Service radio button and click Next. In the next pane, select your organization's hosted service and name the service Sweet_Home_Firewise. Click Continue.

Open the Capabilities selection and check the Feature Service checkbox to enable users to view and manage individual layers.

Uncheck the Tiled Mapping checkbox. Since the Sweet Home extent is a rather small dataset that does not include images or other raster objects, tiling is not necessary. In addition, Map Tiles consume considerable credits. We want to publish data as efficiently and inexpensively as possible.

In the Service Editor, select the Item Description and complete all items. The Summary and Description fields should read Sweet Home, OR Firewise Communities Map. To facilitate searching for individual layers, add the following tags to your list and separate them with commas: Fire Station, Fire District, Fire Lookout, Communities at Risk, Airport, Population, Historic Fire, Assessed Structure, Fuel Model, and Surface Ownership. I try to keep most of my tags in the singular form and avoid redundancy whenever possible. I do not include many abbreviations and only a few acronyms.

Return to Feature Access and select Operations allowed. For now, check only Query. Later, you may authorize other operations for selected users in your organization and in other groups.

Finally, choose Sharing and decide if you will share your service with only yourself (My Content), your organization, or Everyone. In this example, I share with everyone in my organization.

In the upper right line in Service Editor, click Analyze and wait while ArcGIS analyzes the map.

Reviewing Messages before Publishing the Map

ArcMap will generate High, Medium, and Low warning messages. The High and Medium warnings are indicated by yellow triangles with an exclamation point. It should not generate any Fatal Errors, denoted by a red circle containing a white X. The items flagged by this analysis will be handled during the publishing process, so you will not need to do anything.

Finally, click Publish. ArcGIS will prepare and publish the data. You should receive a message indicating that your data has been published successfully. The extra time and effort taken to clean, standardize, and document the ArcMap document prior to publishing helps avoid any fatal errors. After publishing, save your project and prepare to view the Sweet Home map on ArcGIS Online.

Opening the Map in ArcGIS Online

You can use ArcGIS Online to view and analyze the Sweet Home data.

Start your Web browser and log in at arcgis.com/home/login.html if you are not already logged in. Enter your user name and password, just as you did in ArcMap. Verify that you are on your organization's home page and that you are an authorized user.

Open My Content and verify that a Sweet_Home_Firewise Feature Layer and Service Definition have been created and uploaded.

Return to the top line menu. Click New Map from the top line menu. By default, the Topographic basemap will be applied. Click the Basemap button and open the Basemap Gallery. Browse through the gallery and select an interesting basemap. (You can always change it later.)

Click the Add button and select Search for Layers. Type firewise in the Find window and search In My organization. Click Go. The Sweet_Home_Firewise Feature Layer should appear. Select it and click Add.

When your published service loads, ArcGIS Online will zoom to the extent of the Sweet Home District. Once the service has loaded, preview the data, noting that all layers appear to be turned on and that polygon layers are not transparent. When finished, click the DONE ADDING LAYERS button.

ArcGIS Online displays the TOC on the left side of the workspace. All layers will be checked and visible. They are arranged in the same order as they were in the ArcMap document used to create the service and retain the same symbology.

Since all layers appear to be correctly published, save the ArcGIS Online map. In the top line menu, click Save, then Save again. Name the map Sweet Home, OR Firewise Communities Map. Add appropriate tags so you and others can find the map. (Tip: I keep a tag library in a separate document, so I can quickly and consistently locate and assign them.) Complete the summary and save the map in your home folder and click SAVE MAP to finish.

Examining the Map

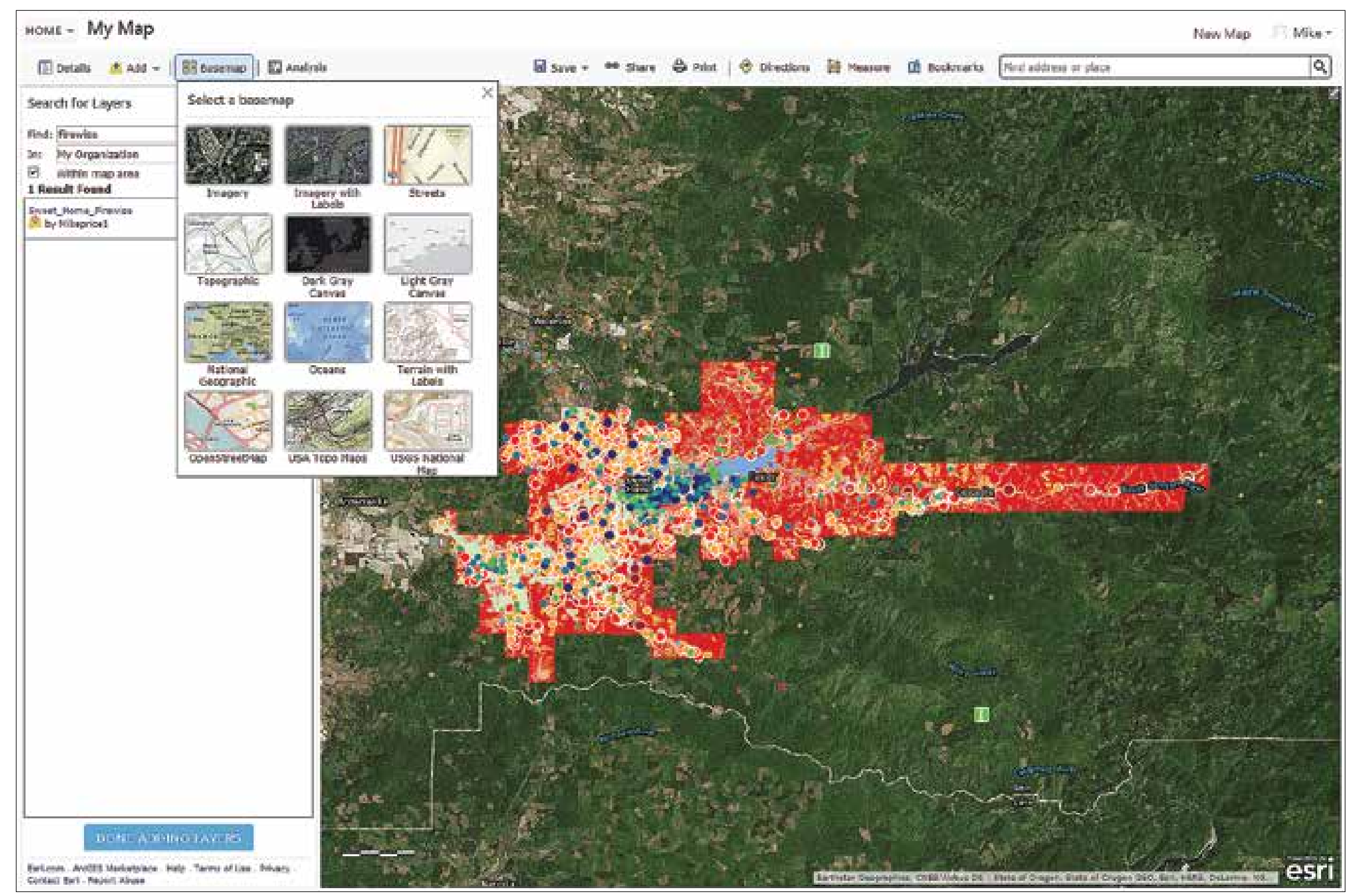
Hold down the Ctrl key and click the checked box for any visible layer to turn all layers off. Check the Surface Ownership, Sweet Home Fire District, and Fire Stations layers to display them. In the TOC, make sure Content is selected. With Content selected, hover the cursor over each layer name to show the tool icons associated with each layer.

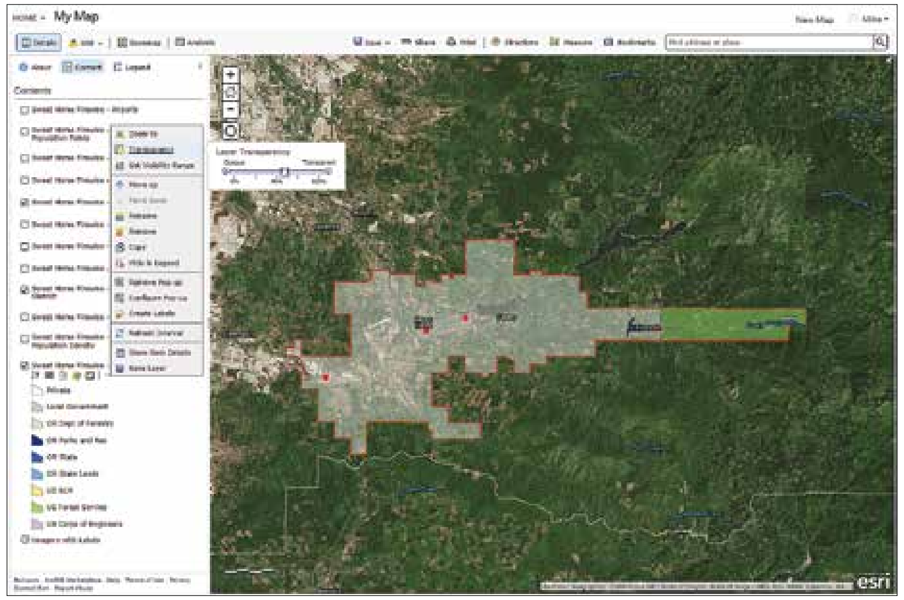
In the TOC, hover the cursor over Surface Ownership and select the ellipsis (three dots) to the right of the tool icons to open More Options. Open the Transparency tool and set the Layer Transparency slider to approximately 60 percent. Click inside the map area to apply it. Turn off Surface Ownership.

Turn on the Census 2010 Population Density layer, display its legend, and set its density to approximately 50 percent.

Locate the table icon under the Census 2010 Population Density layer (it is the second icon from the left) and click it. This table should look just like the attribute table in the source ArcMap document. Momentarily

Once the feature service has been created, log on to ArcGIS Online, locate it in My Content, and add it to a new web map. Change the default basemap.





Adjust the transparency of some layers to improve readability of the web map.

Zoom to and bookmark the Cascadia area of the map. This hosted web map makes information about fire risk available to other agencies and the public using just a web browser.

switch back to ArcMap and check the attribute table, noting the feature count. Minimize ArcMap and return to ArcGIS Online.

Hover your cursor over the Pop_SqMi field name in the table. A small gear icon appears. Click this icon and select Sort Descending. Starting at the top of the column, select all census blocks with a population per square mile greater than 10,000. At least eight small polygons will be outlined in cyan. These are the densest population areas inside the Sweet Home District.

Using Filters and Bookmarks

It is acceptable to select records manually. This encourages you to look closely at the data. However, instead of using manual selection, apply a filter that will show only certain records. In the TOC, locate the Filter button (small funnel on a yellow background) for the Census 2010 Population Density layer. Use the expression builder to create a Filter to show features with Pop_SqMi greater than 10,000. Click APPLY FILTER AND ZOOM TO.

Use a filter to display only certain records in the attribute table.

You can see that nearly all densely populated census blocks are inside the community of Sweet Home. Try filtering all blocks with a population of less that 500 per square mile. According to the National Fire Protection Association (NFPA) definition, these are truly rural blocks. Choose Table > Clear Selection to deselect records. Click the Filter icon again and click REMOVE FILTER to remove the filter before creating a new one on another layer. Experiment with other filters on different datasets.

Next, set several bookmarks. Select More Options for Sweet Home Fire District and click Zoom To. In the top line menu, click Bookmarks, then Add. Name the bookmark Sweet Home Fire District. Turn on Communities at Risk and click on Cascadia, located in the eastern district. Zoom to this point and create a second Bookmark named Cascadia.

Continue Exploring

You are now on your own, free to experiment with other layers, transparency settings, and filters. Imagine ways that this data could be displayed to members of the community to obtain resident input and support for various programs. However, remember that this project really has its roots in a rather unsophisticated ArcMap document.

Acknowledgments

This exercise was created from data collected and analyzed for a real Community Wildfire Protection Program document. Although it has been synthesized to retain some anonymity, it remains quite true to reality. Thanks to the many providers and program participants, including Linn County and its fine GIS department, the Oregon Department of Forestry, the US Forest Service, the US Bureau of Land Management, the National Fire Protection Association and its Firewise Communities program, and my associates at ECONorthwest for all their help and support.

Make More Useful Layers from CSV Files

By Owen Evans, Esri Solution Engineer

This article provides tips for creating more useful hosted feature layers from comma-separated value (CSV) files. While these tips refer to ArcGIS Online, most of them also apply to publishing CSV files as feature layers to an instance of Portal for ArcGIS.

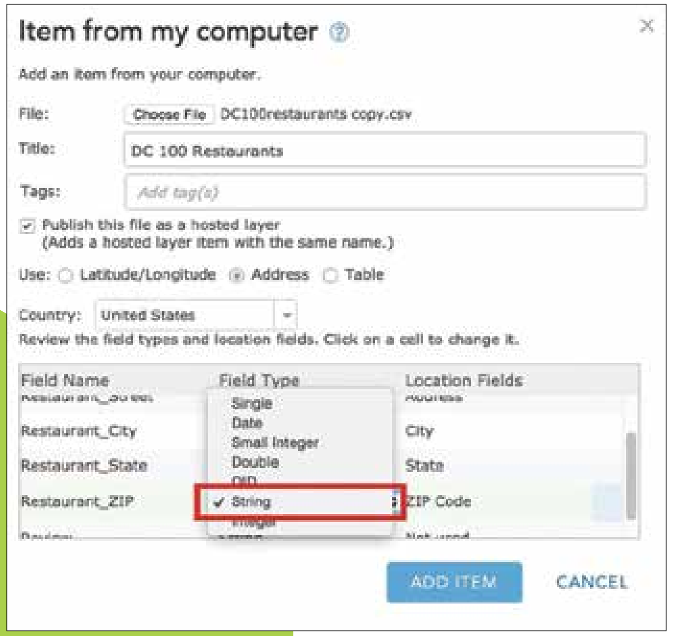
Data Formats and Field Types

Geographic data formats such as the file geodatabase and shapefile have defined field types for each attribute field (e.g., text, numeric, date). When you upload one of these sources to ArcGIS Online, the data types in the source data are used for the fields in the resultant web layer.

However, a CSV file is a basic format that does not contain field types for the columns of information it stores. When you publish simple tabular data from a CSV file to ArcGIS Online, each column of data will be assigned a field type in the resultant web layer.

Field types are important. They determine how the information in a field is displayed and what capabilities are available for the field or the layer. For example, numeric fields can be included in pop-up charts, while date fields can be used to enable time on a layer. Field types also determine which Smart Mapping options are available; for instance, Counts and Amounts options are only available for numeric fields.

Choose the best field types for your CSV files during publication so you won't have to adjust field formatting settings later.



Here are guidelines for each field type used in ArcGIS Online that includes the information best suited to each type.

String

Use the string format for text fields with mixed alphanumeric characters as well as ZIP codes, FIPS codes, numeric IDs, telephone numbers, and any field that should not be displayed as a number with comma separators or decimal places. For example, the ZIP code 83706 should not be shown as 83,706 or 83,706.00.

Integer

Use the integer format for numeric fields that represent a count (e.g., population figures, the number of cars) or other whole-number or integer values (such as budget figures provided as whole dollar amounts). By default, integer fields display comma separators and no decimal places.

Double

The double format is appropriate for numeric data that will have decimal places such as averages or normalized fields. The default display format is two decimal places with comma separators.

Date

Use the date format for data that contains dates and/or times. This field type will allow the layer to be time enabled and has various date/time formatting options.

Publishing Feature Layers to ArcGIS Online

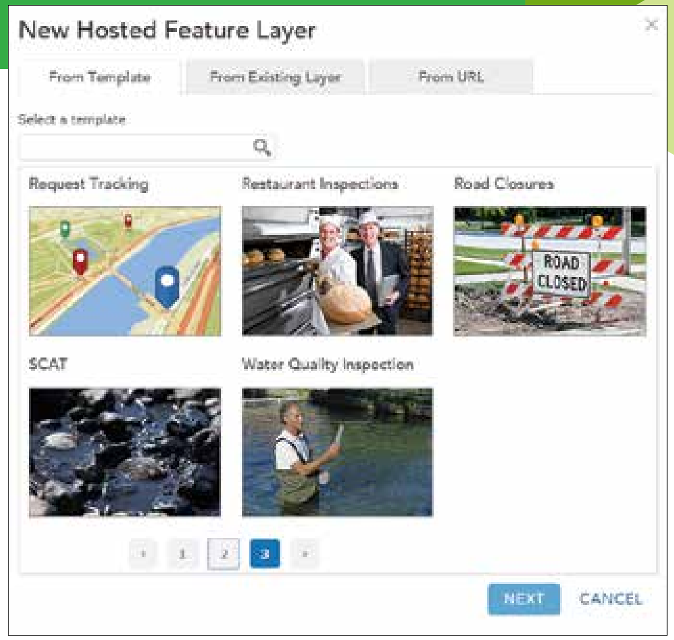
ArcGIS Online evaluates the first few rows of data in a CSV file to determine which field type to use for the resultant hosted feature layer. The field type can also be established if the field name matches the common field names associated with specific field formats shown in Table 1.

Format	Associated Field Name
String	ZIP, Address, Street, City, State, Country
Double	Latitude, Longitude, Lat, Long, Lon, X, Y
Date	Date, Time

Table 1: Common field names associated with specific formats

Other field names may be recognized when geocoding in locales other than the United States. For example, "prefecture" will match if the selected country is Japan.

ArcGIS Online does a good job choosing field types for CSVs, but there are some cases where you may need to override the suggestions. For instance, a ZIP field in your CSV might be named "Office ZIP+4 Code" or something else that ArcGIS Online doesn't recognize.



Create a layer for collecting information more easily using the data collection templates available from ArcGIS Online.

Another case is when a field that contains dates is set as string. In that case, the Enable Time option is not available for the layer.

If you choose the best field types during publication, you won't have to adjust field formatting settings later, and you'll ensure the desired styling and configuration options will be available on the resultant layer.

To pick field types for a CSV dataset, publish the file using the Add Item button on the My Content page. Then review the field types in the list and click any types that you want to change to select a different type.

You can always add or remove fields later using the Add/Remove Fields tool in the Table view or change the service schema if you have admin rights to the layer.

You also need to set the fields that are used to geocode your data under the Location Fields column. Most fields used for location (street, city, country) will be set to String type in the resultant feature service, except X, Y, Lat, or Long, which will be set as Double type.

More Tips

Change the name of your CSV file to something readable and identifiable before uploading it.

Revise the field names in your CSV so they are short and readable. It's okay to include spaces because ArcGIS Online will use field names with spaces as field aliases.

If you are creating a layer for collecting information, the data collection templates available from ArcGIS Online provide an empty feature layer with a focused set of fields and field types that can simplify the layer configuration in some cases. To use these templates, log in to your ArcGIS Online account and go to My Content > Create > Feature Layer and choose an appropriate template from the From Template tab.

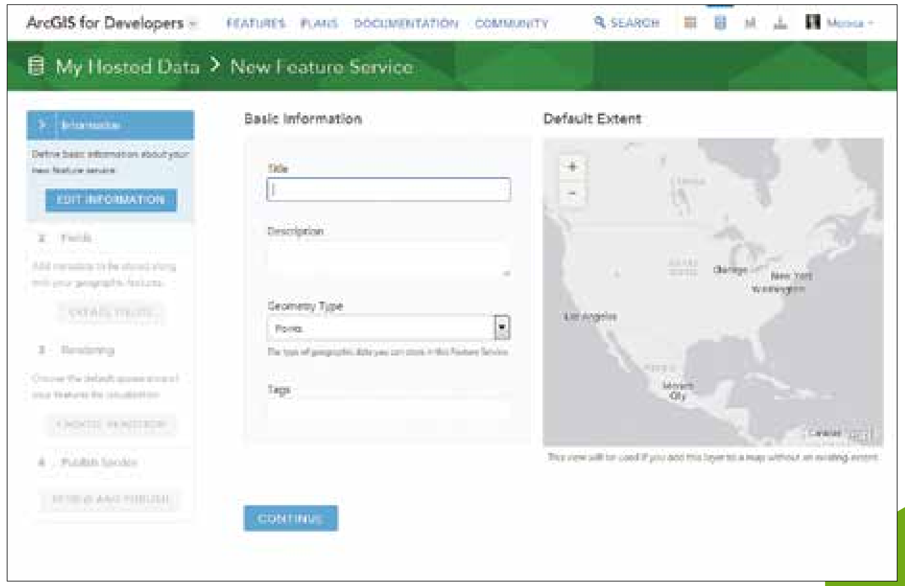
You can also create a new, empty feature layer based on the schema of an existing service by going to My Content > Create > Feature Layer and clicking the From Existing Layer tab.

Create feature layers from scratch at the ArcGIS for Developers (developers.arcgis.com) website. You don't need a Developer account to use this site. Log in with your organizational account, click Hosted Data (the cylinder icon at the top right of the page), then click NEW FEATURE SERVICE and enter the information to define your new feature service.

About the Author

Owen Evans is a solution engineer with the Esri national government sales team located just outside Washington, DC. He has been with Esri since 2004, and his main areas of interest are ArcGIS for Server, cloud computing, and online GIS. He contributes to the ArcGIS Online and ArcGIS for Server blogs and collaborates with the Esri Story Map team on projects and best practices documents.

You don't need a Developer account to create feature layers from scratch at the ArcGIS for Developers (developers.arcgis.com) website. Just log in to your ArcGIS Online organizational account.



Quick and Simple Ways to Tame Point Data

By Monica Pratt, *ArcUser* Editor

If you make maps, this scenario is probably familiar. You get or find data about something really interesting. Most often it is a lot of point data. If you try to display all that data on a map, those points will overwhelm the map and communicate nothing.

This is especially true if the map will be viewed online or on the small screen of a phone or other mobile device. Super busy maps that show lots of data but no patterns are confusing and boring. Maps should provide context through an organized view that shows the shape of the data.

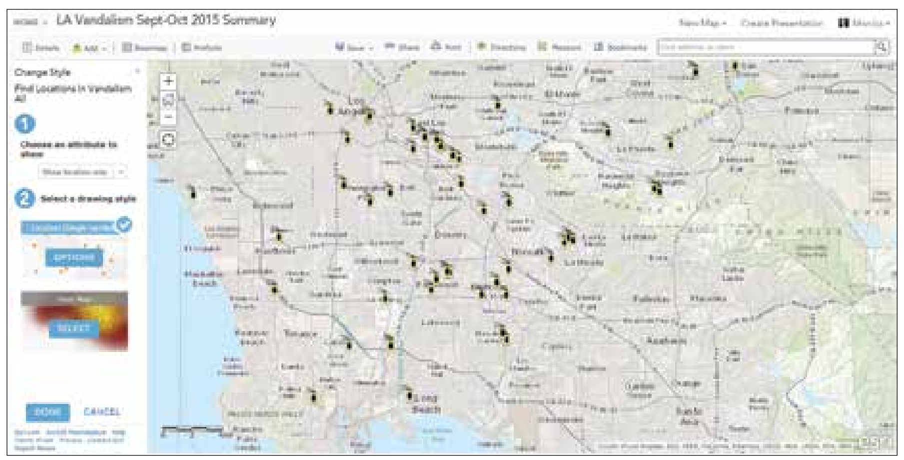
However, before you start mapping anything, ask yourself a very important question: Does this data deserve to be mapped? Perhaps the message is so simple it doesn't need to be mapped. What insights will mapping provide about the data? If the answer is none, stop right there.

If mapping the data is potentially valuable, you will need to ask yourself two more questions to come up with an effective solution:

1. What do you want to communicate with this map?
2. What aspect of the data will tell that story?

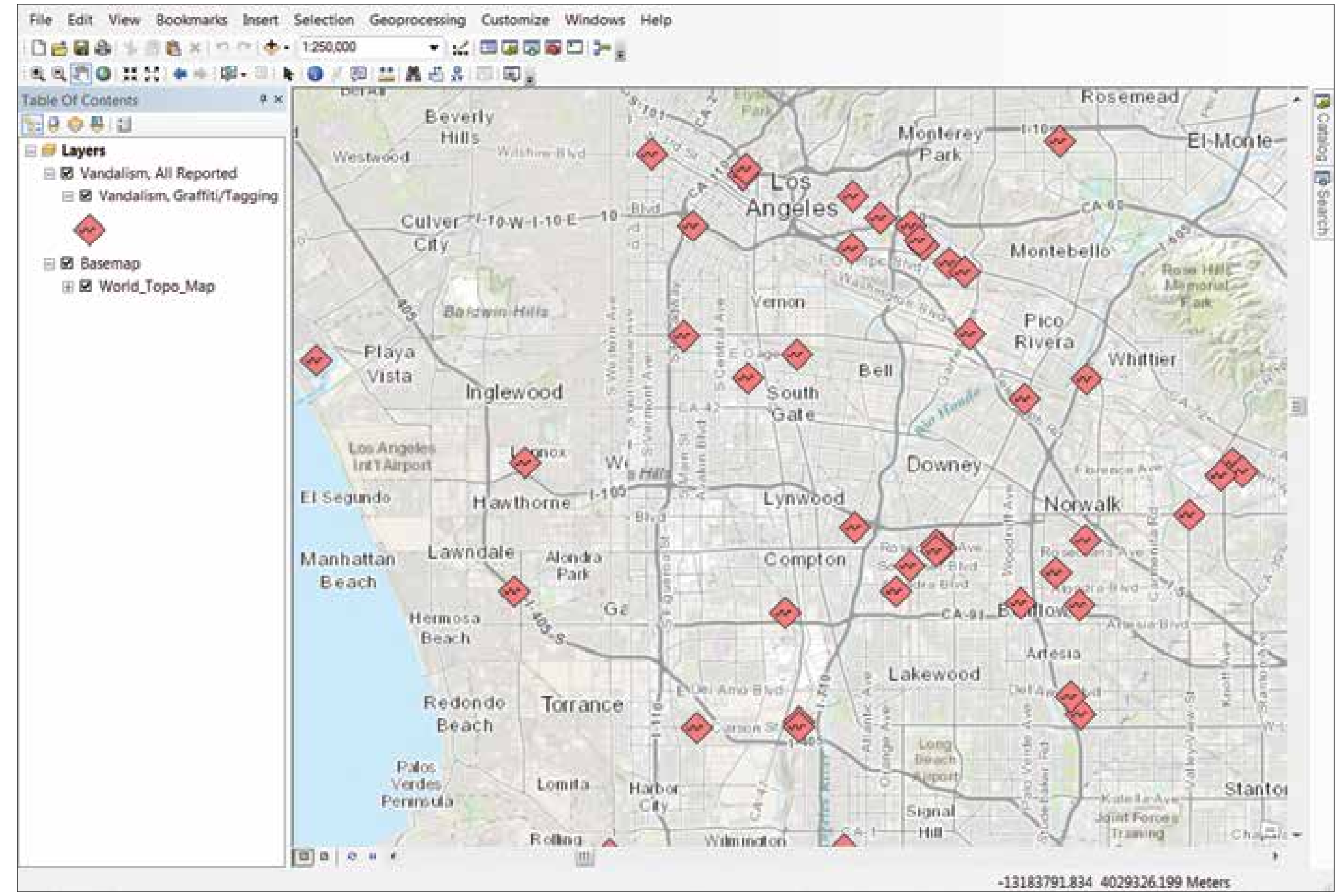
The second question is meant to encourage you to fight the urge to show *all* the data. Take a breath, step back, and think about the specific message you want to communicate with the map. The temptation to show all the data is often hard to resist even when only a portion of the data is relevant. This goes along with the tendency to overestimate the ability to see patterns in a sea of points.

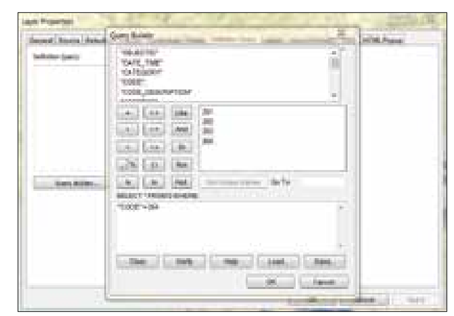
To use just the data that will communicate that message, you will typically need to suppress extraneous data and highlight the relevant aspects of the data you show. This article will give you several quick and easy techniques that will help you accomplish this using the tools in ArcGIS Online and ArcGIS for Desktop.



Showing all categories of vandalism is not useful if the map's message is to show just the graffiti incidents.

Using the Filter tool in ArcGIS Online will select just the graffiti incidents, making the message much clearer.





You can filter data in ArcMap using a definition query.

Dealing with All Those Points

Before you even start mapping data, there are a couple of things you can do to make the process more efficient by making the data more manageable. Often, point data is supplied as a comma-separated value (CSV) or a Microsoft Excel file. With either format, use Excel to inspect the data. Omit any unnecessary fields and select out only the type of records you need. This will also help avoid encountering the default 1,000-record limit for ArcGIS Online hosted layers.

To make the data compliant with ArcGIS, eliminate any blank records, ensure there are no empty fields or duplicate field names, and check that field names conform to ArcGIS naming conventions. For more information on using Excel files in ArcGIS, see the article "Always and Never When Formatting Excel Tables" in the Fall 2015 issue of *ArcUser* and "Best Practices When Using Excel Files with ArcGIS" in the Spring 2012 issue of *ArcUser*.

The ArcGIS platform has lots of tools for wrangling and displaying data that enable techniques for effectively communicating the message in the data. The smart mapping tools provided by ArcGIS Online do a lot of the heavy lifting for you by providing intelligent defaults and sophisticated functionality that is easy to use.

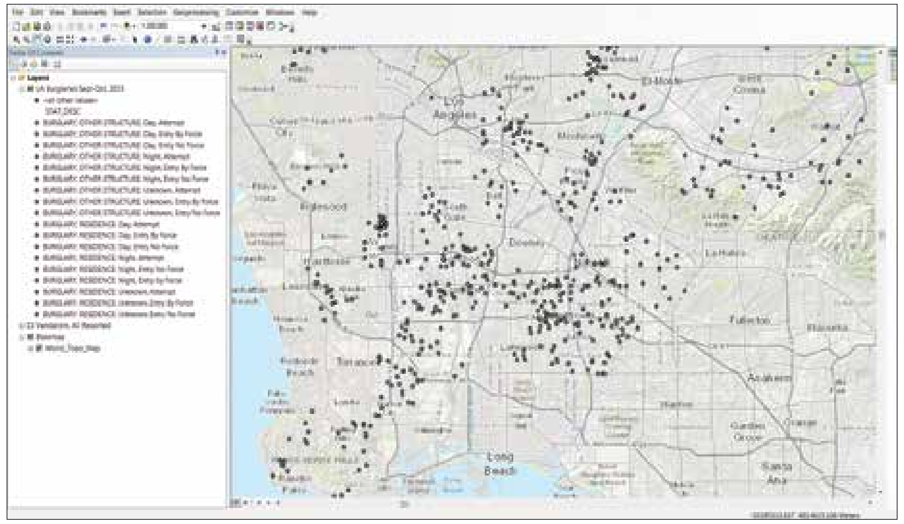
Filtering Data

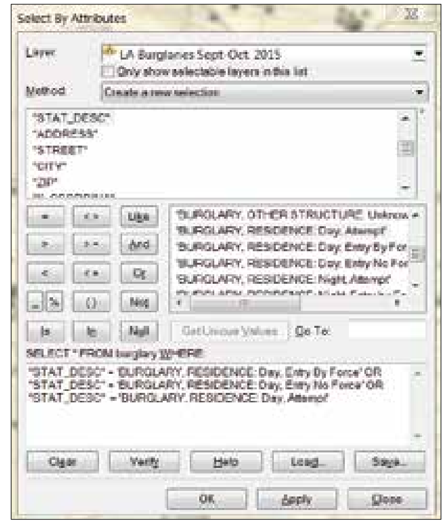
Filtering features is one of the simplest methods for eliminating clutter in a map. For example, if you were making a map to show where graffiti is a problem in Los Angeles, you might download data from the Los Angeles County Sheriff. Data for Part 1 and Part 2 crimes for specific time periods is available for download in CSV format.

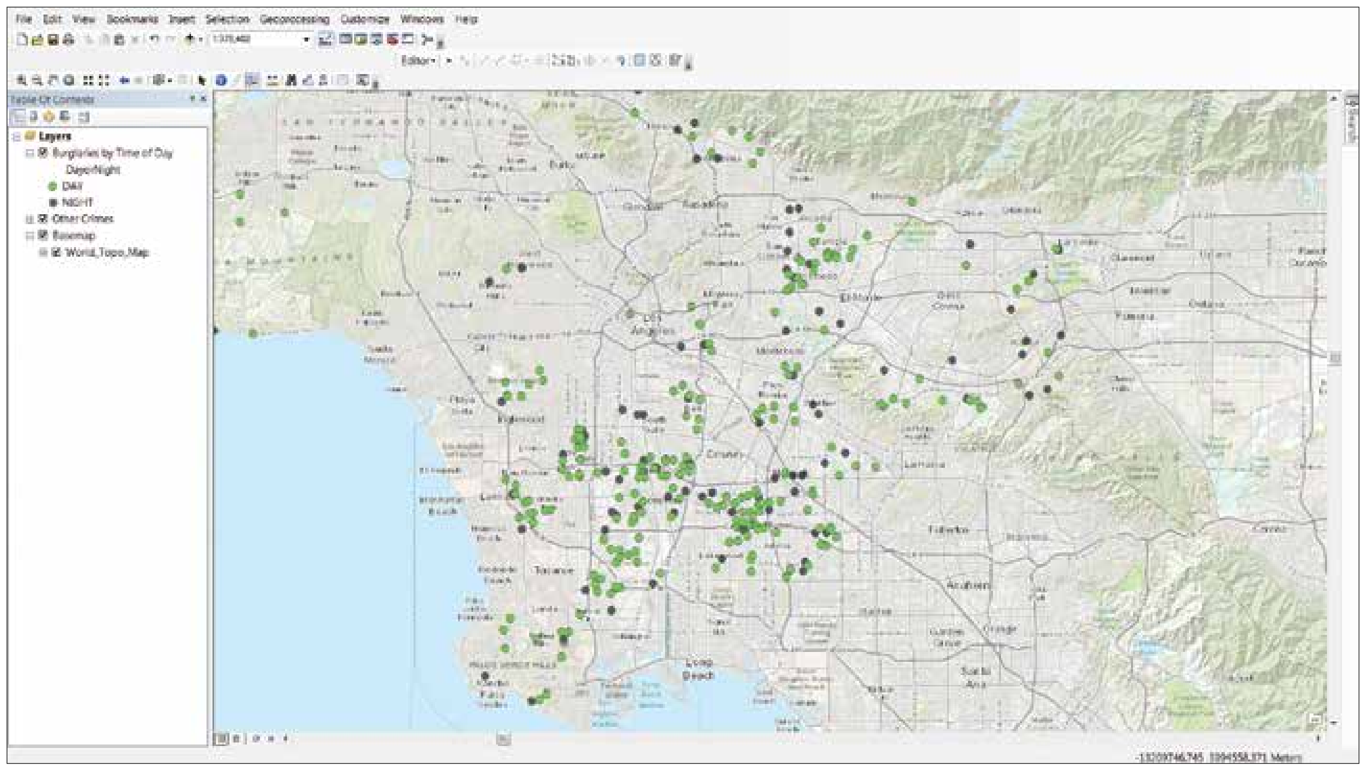
After downloading this data and opening it in Microsoft Excel, you could remove records for all crimes except vandalism (the category that encompasses graffiti) before adding it to a map created using ArcGIS Online or ArcMap in ArcGIS for Desktop.

Because CSV is a basic format style, it does not contain field types for the columns of data it stores. To learn more about how to ensure CVS files are added to ArcGIS Online in the most useful format, see "Make More Useful Layers from CSV Files" in this issue.

Once data for vandalism is added, just the locations related to reported graffiti can be highlighted by filtering the data. ArcGIS Online has a Filter tool available directly underneath the layer in a web map







Although the data may have many subcategories (upper map), if the map's message relies on comparing a few high-level categories, consolidate categories (lower map).

when it is in the map viewer. Clicking the Filter icon brings up an expression builder that walks you through the creation of one or more expressions that can be applied to the layer to filter data. Filtering combined with Set Visibility Range can give you greater control over the viewer's experience.

In ArcMap, you can use definition queries to filter data. Definition queries select only features that you want to display without changing the underlying data. Create a copy of a layer you want to filter and rename it with a name that indicates the characteristic used to filter it. Double-click the copy layer to bring up its Layer Properties dialog box. Click the Definition Query tab, then the Query Builder button. Use the Query Builder to create a SQL statement that selects the records you want to show. You can also export the features selected by the definition query as a feature class.

Too Many Categories

Just as your message can be lost in a mass of mapped points, it can also be lost in a map that contains too many categories even if that is how the data came to you. Although the data may be broken down into very detailed subcategories, the map's message may rely on the comparison of just a few high-level categories of that data.

For example, if you were comparing the number of residential burglaries that occurred during the day with those that occurred at night, you could query out and consolidate the subcategories for residential burglaries (forced entry, no forced entry, unknown) by incident time and symbolize incidents in the resultant two categories (day and night), making the message clearer.

Sometimes grouping data into just two categories—all the data above and below a certain threshold—tells the story. The threshold can be one in quantity or time. If there is an important breakpoint in the data, use that to base your categories. This will communicate the most important aspect of the data at a glance.

Points Don't Always Make the Point

Most of the time, showing the exact location of every data point is not going to tell the story. What *is* useful is symbolizing the points in a way that reveals patterns and structure in the distribution of those points.

Even though the data you received may have been given to you as point data, that doesn't mean it has to stay as points. Point data may be much more effectively presented as a surface or aggregated in some fashion. Aggregation can be based on time as well as location. For example, perhaps you received hourly data on some phenomenon, but it will make more sense and tell a clearer story if it is aggregated to days or even week or months.

The bottom line: Points don't have to stay points. Some easy methods for meaningfully aggregating point data include heat maps and hot spot maps. Both heat and hot spot mapping are part of the smart mapping tools in ArcGIS Online. In ArcMap, heat maps and hot spot maps can be generated using the Spatial Analyst tools that are available with the ArcGIS Spatial Analyst extension.

Heat Maps

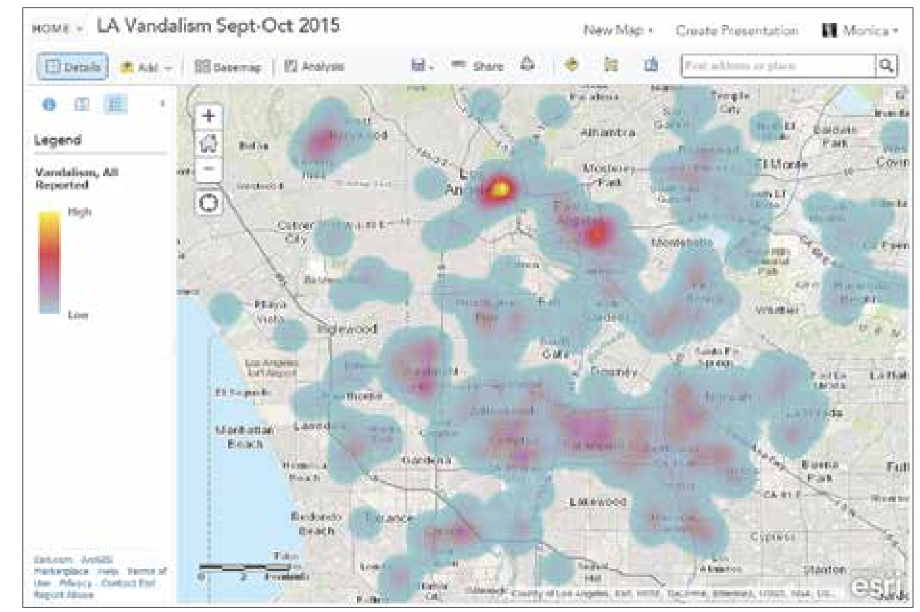
Heat maps are one method for quickly inspecting the distribution of point data. They let you see structure that you might otherwise miss by showing where points cluster while still accounting for all the points in the data.

Hot Spot Maps

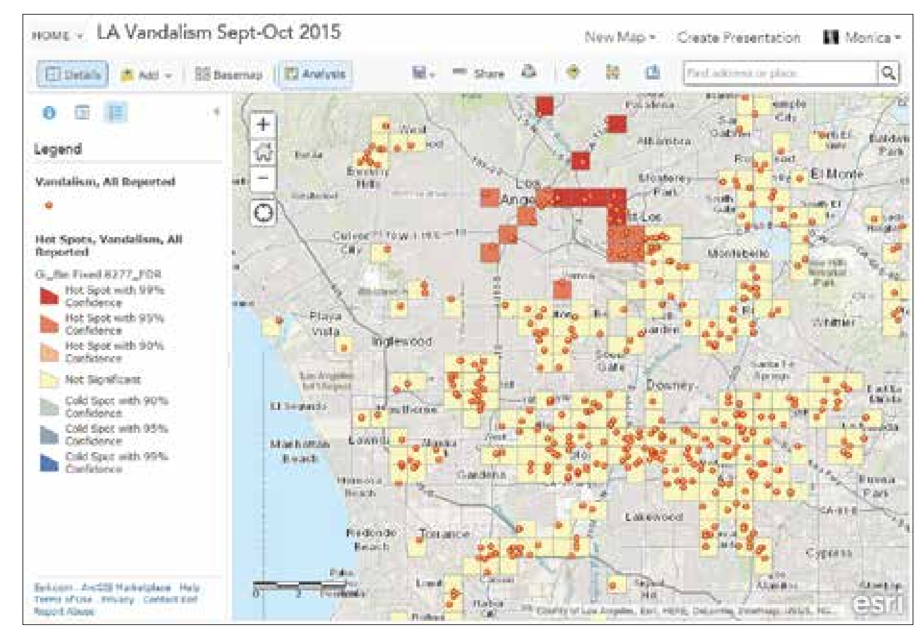
Hot spot maps, though similar in appearance to heat maps, show statistically significant spatial clustering of points in the data and can uncover unexpected hot spots (red) and cold spots (blue) of high and low values.

Getting to the Point

Your job when making a map is to clearly communicate a message that can be easily and quickly understood. This is particularly important if it is a web map that might have only a few seconds to capture the map viewer or if it will be viewed on a smartphone or other mobile device. To accomplish this, you need to understand the data, formulate the message, and take advantage of the tools in ArcGIS to provide insight into point data and get your message across.

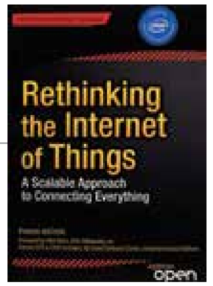


When the exact location of each point may not tell the story, creating a surface may communicate more information. A heat map can show where points cluster rather than the location of each point.



Hot spot mapping goes beyond visual inspection of a surface and identifies statistically significant clustering of points.

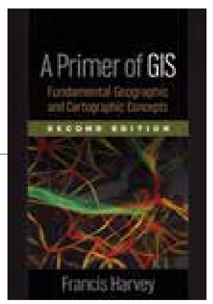
GIS Bookshelf



Rethinking the Internet of Things: A Scalable Approach to Connecting Everything

By Francis daCosta

This book bypasses the hyperbole of many books about the Internet of Things (IoT) and addresses the qualitative differences between the Internet as we now know it and the Internet of Things that is evolving. As billions of sensors and actuators are wired up, the architecture of the Internet will have to change to scale up and accommodate differences in not only the quantity but also the type of information exchanged by machine-to-machine connections that do not have human involvement. The author, who has a background in autonomous robotics, embedded systems, big data analysis, and wireless networks, describes how a network could be built to maximize the potential of the IoT. Thought leaders, executives, and leaders in the development of standards for the IoT are the target audience for this book, but it is of interest to a much wider technology-minded audience. *Rethinking the Internet of Things* was a 2014 Jolt Award Finalist, the highest honor for a programming book, although it contains no code. Apress, 2013, 192 pp., ISBN-13: 978-1430257400

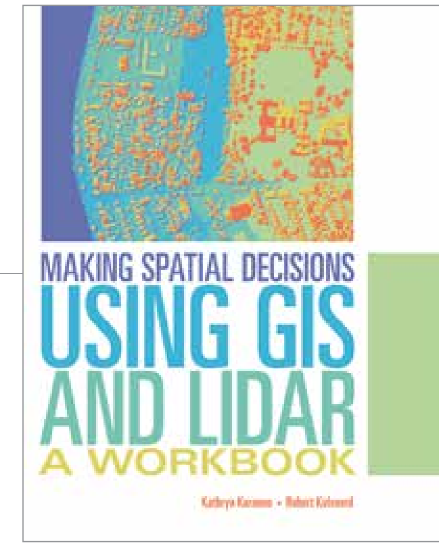


A Primer of GIS: Fundamental Geographic and Cartographic Concepts, Second Edition

By Francis Harvey

This book differs from many introductory GIS books in that it is concept-centric and software agnostic. The first section covers the goals of cartography and geographic science, how we represent the world, and a brief history of GIS. The second section provides a background in the technologies associated with GIS. The third section contains information on techniques and practices. The fourth section addresses the fundamentals of geoscience analysis. This book is designed as a classroom text. Each chapter contains further readings, web resources, exercises, and questions. The author heads the Department of Cartography and Visual Communication at the Leibniz Institute for Regional Geography and is a professor of visual communication in geography at Leipzig University in Germany. He currently serves as chair of the International Geographical Union Commission on Geographic Information Science. The Guilford Press, 2015, 360 pp., ISBN-13: 978-1462522170

Make Better Decisions Using ArcGIS with Lidar Data



A new book published by Esri teaches how to use GIS to analyze and visualize lidar data.

An optical remote-sensing system, lidar uses a laser to measure topography, vegetation, objects such as buildings, and the ocean floor at some depths. Data collected from lidar can be used to create highly accurate elevation and terrain models.

Lidar is widely used because it can produce higher-quality results than traditional photogrammetric techniques more cost-effectively. ArcGIS has many tools for managing lidar point clouds and deriving information products.

Making Spatial Decisions Using GIS and Lidar: A Workbook is a college-level textbook for students and geospatial technology professionals. It assumes readers are familiar with lidar and have some experience using ArcGIS for Desktop. Its 10 learning modules focus on how to use the geospatial analysis tools in ArcGIS for Desktop with lidar data to answer questions and make informed decisions about real-world situations.

Exercises include determining how much land to excavate for an underground parking garage, locating cell phone towers for maximum signal coverage, placing solar panels based on the amount of solar radiation in an area, analyzing how a coastline has changed after a major hurricane, and making flood insurance rate maps based on hurricane inundation zones.

The workbook covers basic lidar data analysis techniques, 2D and 3D modeling, volumetric analysis, shadow maps, forest vegetation height analysis, and other lidar-related analyses.

Making Spatial Decisions Using GIS and Lidar: A Workbook is the third in the Esri Press Making Spatial Decisions series written by Kathryn Keranen and Robert Kolvoord. Keranen is an instructor at James Madison University in Harrisonburg, Virginia. Kolvoord is a professor of integrated science and technology at James Madison University. They also wrote *Making Spatial Decisions Using GIS and Remote Sensing: A Workbook* and *Making Spatial Decisions Using GIS: A Workbook*. Esri Press, 2015, 264 pp., ISBN: 9781589484290

Certification Superstars

Gain Expertise and Satisfaction

By Suzanne Boden, Esri Training Services

Stefan Jaquemar, Adam Nicinski, Steven Beothy, Marek Dorsic, and Wee Leng Ang belong to an exclusive club. These five overachievers—collectively—hold 82 Esri technical certifications that span all three certification domains: Desktop, Developer, and Enterprise. They amassed these certifications in just five years since the program launched.

Each has demonstrated not only expertise in multiple ArcGIS domains but also the motivation and time management skills required to successfully prepare for and pass a certification exam not once but many times.

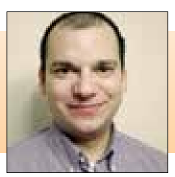
Stefan Jaquemar
17 Certifications

Consulting and Support at SynerGIS

Stefan Jaquemar is required by his employer, SynerGIS, to hold an Esri technical certification. SynerGIS, the Esri distributor in Austria and Slovakia, believes that having Esri-certified staff showcases the company's ArcGIS platform expertise to its customers.

"My focus at work is ArcGIS for Server, Portal for ArcGIS, and enterprise geodatabases. That's the reason for being certified in these areas. The certifications give me confidence in teaching, consulting, and supporting customers, partners, and colleagues. Once I started with certification, I nearly got addicted to it," he joked.

The new ArcGIS Desktop Entry and the ArcGIS Desktop Professional are the only Esri certifications missing from Jaquemar's portfolio. Could 18 certifications be on the horizon? "My colleagues sometimes tease me that I should finally take the ArcGIS Desktop Professional. We will see."



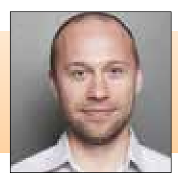
Adam Nicinski
17 Certifications

Developer at Comarch

In addition to his 17 Esri certifications, Adam Nicinski holds a master's degree in spatial information systems. He also submitted the winning entry in the Esri Data Viz App Challenge 2015.

Over the last few years, Nicinski has developed a winning exam-preparation regimen. "Every time I was preparing for an exam, I went through its qualifications and skills measured, published on the Esri Certification website, and studied in depth on those topics, referencing my hands-on experience with the software. Also, I reviewed the Esri help documentation extensively."

Nicinski's desire to earn particular Esri certifications evolved over time. "The main driver for becoming Esri certified was to obtain authoritative confirmation of my proficiency with the ArcGIS platform. The order in which I obtained certifications mirrors my Esri software experience. I started with desktop, then got familiar with geodatabases and server technology, and lastly started using Esri's application development tools. This approach has been a natural way for me to build my professional career."



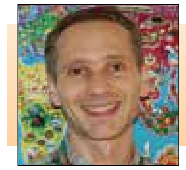
Steven Beothy
16 Certifications

Senior Certified ArcGIS Instructor at Esri Canada

Like other overachievers, Steven Beothy's path to certification started with a job requirement. "As an instructor with Esri Canada, I was required to be certified in each domain we taught in. I saw it as a great way to prove my knowledge and have credibility in the eyes of my students."

From there, he grew to appreciate certification for its professional development benefits and potential to grow his career. "It is a means to reassure students in my classes on my knowledge of GIS and Esri software, but it is also a benefit for my career," Beothy said.

While his 16 certifications support future success, they are also highly relevant to Beothy's present. "What I like most about Esri certifications is that they test me on software that I use on a daily basis," said Beothy.



Marek Dorsic
16 Certifications

Solution Architect at ArcGEO Information Systems

Marek Dorsic's motivation for pursuing Esri technical certification was twofold: he wanted to verify his existing ArcGIS knowledge and also identify areas for future professional development. "The exams are an opportunity to upgrade my knowledge. They help me verify that the procedures I am using for various tasks, like data loading, system upgrades, and even problem solving, are sound and correct," he said.

As an employee of the Esri distributor for the Slovak Republic, Dorsic is eligible to take beta exams. Some of his test center experiences have been memorable, and he shared one.

"The beta exams take four and a half hours," Dorsic said. "During one exam, getting a glass of water at the test center was a struggle. After reading and answering dozens of really complex questions, my concentration was gone. I wished to have a cup of strong coffee. Then, after the 70th question, the exam application refused to load the next question. I managed to break the exam software! But on the good side, while the technician was solving my problem, I was offered and could enjoy an espresso."

Wee Leng Ang
16 Certifications

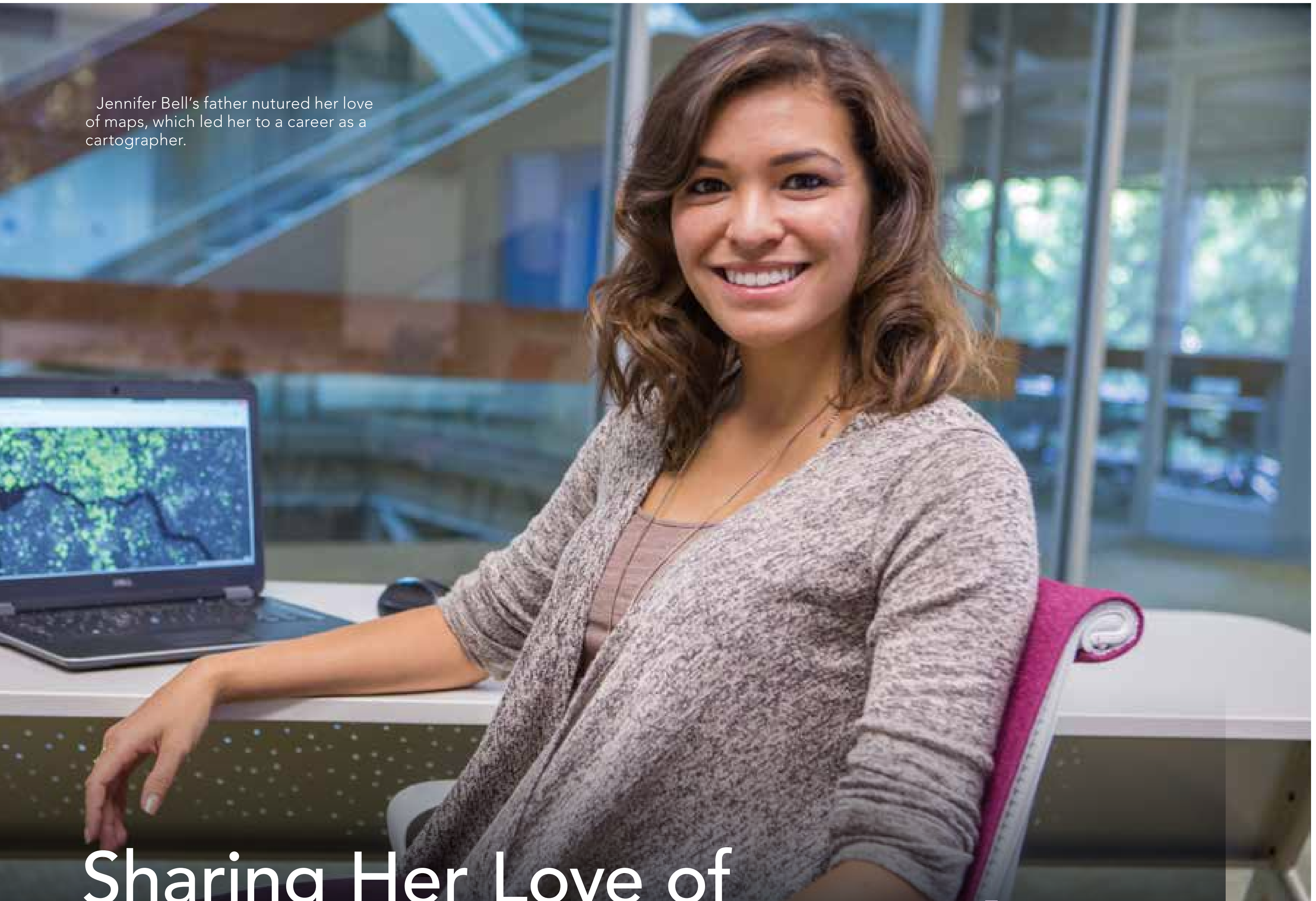
Senior System Manager at Esri Singapore

Wee Leng Ang sees direct workplace benefits from time spent preparing to take a certification exam. "The exam questions are relevant and practical to the implementation of ArcGIS," said Ang. "These are real-life workflows, issues, and questions one will face when implementing ArcGIS solutions. By taking the exams, I have the opportunity to look into them long before encountering them."

"Esri Singapore is an authorized training center, and we are expected to be certified in order to conduct Esri instructor-led courses," he continued. "With this in mind, I did not choose any specific certification domain or level but just took the exams as they were released. Before I knew it, I had taken all the exams offered by Esri!"

The workplace benefits continue to accrue long after Ang has taken an exam. "As part of the technical team at Esri Singapore, I am involved primarily in presale and training. Being a presale consultant, I am expected to have an in-depth knowledge of ArcGIS products," Ang said. "Because we are Esri certified, users and potential customers are more confident in the advice that we provide."

To learn more about the Esri Technical Certification Program, including the qualifications and skills measured for each exam, visit esri.com/certification.



Jennifer Bell's father nutured her love of maps, which led her to a career as a cartographer.

Sharing Her Love of Geography

By Carla Wheeler, *ArcWatch* Editor

On November 18, 2015, Monica Taylor, a teacher at Central Middle School in Riverside, California, stood in front of scores of impressionable young minds hoping her guest for the day would spark their interest in geography and mapping on a very special day—GIS Day.

"Who knows what a cartographer does?"

Taylor asked the students at the assembly. The group included the seventh and eighth graders enrolled in the life sciences and physical science classes that she teaches. "A cartographer is a mapmaker. It's not old school, where you are drawing *[maps]* on paper. They make them on computers," she said.

A Passion for Geography

Taylor then introduced a real, live cartographer to her classes: Jennifer Bell. The talented, upbeat 26-year-old is a cartographic product engineer at Esri in Redlands, California. Bell often smiled as she told stories about working at what she describes as her "dream job" at Esri.

Her work focuses on urban systems and transportation. These areas are of special interest to her because she is concerned about poverty; social inequality; and issues related to food, transportation, and health accessibility. Bell has created beautiful web maps with bold colors that highlight everything from global poverty to job accessibility. She often says she likes to "put the art back into cartography."

Bell was born in Saudi Arabia, where her father worked for the Saudi Aramco Oil company, and she traveled extensively as a child. This made her more spatially aware of the world than most young Americans.

Bell said her father, who died in 2005, loved to travel. She credits him with exposing her to maps and spatial concepts at an early age. "We had a huge atlas. Before a road trip, he would set it down on the table and say, 'This is where we are, and this is where we are going.' And he would ask me, 'Which way should we go?' And I would guess and we would highlight the route. And then we would get in the car and I would have the map and I was the navigator. I was in charge of telling him what road we were on and where to turn."

The Importance of Geography

She went on to obtain bachelor's and master's degrees in geography from the University of Georgia. Passionate about her career as a geographer, Bell also hoped to elevate the kids' sense of geographic awareness. She brought her show-and-tell presentation of online maps and videos to Central Middle School to demonstrate how maps relate to students' lives and their future careers. She also wanted to give them a taste of what she does at work.

Taylor sees geography as an avenue for students to better understand the world around them. She said that some children do not know where California is located on a map.

Her concerns are well-founded. A recent report issued by the United States Government Accountability Office entitled "Most Eighth Grade Students Are Not Proficient in Geography" states that 75 percent of eighth graders in the United States did not demonstrate competence in the subject.

While underscoring the importance of geography in a world where people use maps on their cell phones to find places and mapping is used to track diseases like Ebola, the report says that misconceptions within the education community continue to exist about what geography studies involve.

The report cites additional problems that include a lack of professional development in geography among teachers, poor instructional materials, and "limited use of geographic technology in the classroom."

In a GIS Day presentation, Esri cartographyer Jennifer Bell shared her passion for geography with schoolchildren at Central Middle School in Riverside, California.

Telling Stories with Maps

"Do you know what today is?" Bell asked the middle schoolers. Some were attentive; others were squirming in their seats.

Hands shot up and shouts rang out. "Thanksgiving!" "Earth Day!" "Veterans Day!"

"No," Bell said, laughing. "Today is GIS Day."

"What?" a student said.

"GIS stands for geographic information systems, technology used to create maps that can be viewed online and on your cell phones," Bell said.

GIS Day, held annually in November, celebrates GIS technology. "GIS is like geography on a computer," Bell told the students, who do their lessons on Chromebooks issued by the Riverside Unified School District. Cartographers, scientists, and others, she said, use GIS mapping software created by Esri to turn information collected about practically anything imaginable—birds, diseases, earthquakes, crime, sports, and weather—into maps that tell stories.

Bell showed the students a series of Esri Story Map apps. These mapping applications tell stories using a mix of maps; imagery; text; and multimedia such as photographs, videos, and music.

The *Discovering Liquid Water on Mars* story map included NASA imagery that contained an element of mystery: strange-looking marks running down steep Martian slopes. "What do you think those dark streaks are?" Bell asked. "Water!" several children said in unison. "They look like water, but they are hydrated salts, proof that *[salt]*water is on the planet," Bell said.

The children's eyes really popped when they viewed a map of Kathmandu, Nepal, which was devastated by a magnitude 7.8 earthquake in April 2015. The map contained before-and-after satellite imagery. Bell used a slider feature in the map to show them what the city looked like before the quake and afterward, when many buildings had turned to rubble.

Some of Taylor's students are studying earthquakes, which gave Bell an opportunity to talk about maps they can make using their Chromebooks and ArcGIS Online, free online mapping software that Esri is providing to all the K–12 schools in the United States as part of the ConnectED initiative.

"Mrs. Taylor got all of you guys ArcGIS Online accounts," said Bell. "*[Now]* you have the resources to make maps." Taylor plans to take advantage of these accounts. Students can start out by creating story maps about topics they find interesting, such as sports, trucks, and vacations.

Bell will return to Central Middle School to teach the instructors how to use ArcGIS Online and work with their school accounts. By summer 2016, Taylor and other teachers will have access to instructor resources for *The ArcGIS Book*, which introduces web GIS.

Instilling a Love of Maps

While teachers play a role in geography, Bell also thinks parents could do a better job introducing their children to spatial concepts, even if it is just quizzing them about how to get to the grocery store.

If there was one thing Bell wanted to leave with the children at Central Middle School, it was that "Geography helps you understand the world around us."

She did a pop quiz to help the young people understand that maps can relate to anything in life. "What do you want to be when you grow up?" Bell asked the students.

"A neurosurgeon," said one student.

"A neurosurgeon can map the human brain," said Bell.

"A veterinarian!" said another.

"We can map the spread of diseases and predict where they will go next," said Bell.

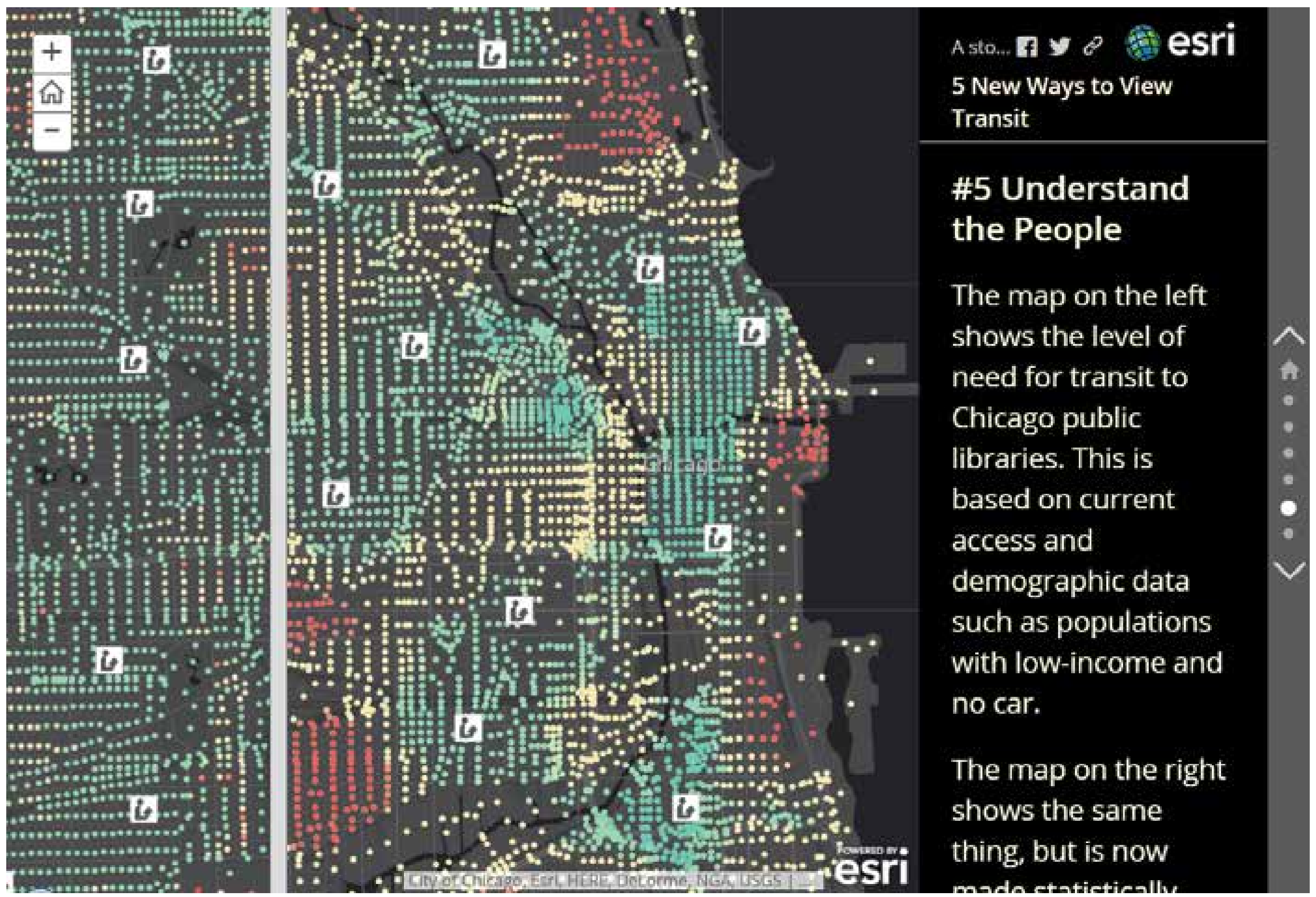
"A lawyer," said a third.

"You can track where your client has been and provide an alibi," Bell said.

Bell spoke to more than 500 students over four hours. Before she left Central Middle School on GIS Day, she learned that three of them had expressed an interest after the assembly to join the science club.

That made her smile.

Bell's work at Esri has focused on transportation and urban systems.



A shape model shows Mercury's gravity anomalies, which indicate by color the planet's subsurface structure and evolution. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

MESSENGER DATA REVEALS

Another Side of Mercury

An interview with planetary geologist Paul K. Byrne

In 2015, NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, the first probe to orbit Mercury, ended its 11-year mission by slamming into the surface of the solar system's innermost planet.

Before its violent demise, MESSENGER sent imagery back that, coupled with imagery from the Mariner 10 flybys in 1974–75, has enabled the mapping of 100 percent of the planet's surface, with 98 percent of it at a resolution of 1 kilometer or better.

Mercury is the least explored of the terrestrial planets. Mapping its surface will help scientists learn more not only about its formation and geologic history but also about that of the other terrestrial planets. ArcGIS for Desktop and its extensions play a central role in managing and transforming photogeological and topographic data into maps.

Planetary geologist Paul K. Byrne, assistant professor of planetary geology at North Carolina State University and a MESSENGER visiting investigator, explained to Esri writer Matthew DeMeritt how mapping helped to interpret the remote-sensing data collected by MESSENGER and how GIS enhances investigation of the solar system.

DeMeritt: How did you end up becoming involved with the MESSENGER mission, and did your GIS background help you become a visiting investigator? Was GIS part of the mission from the outset?

Byrne: I was very fortunate to join the MESSENGER team as a postdoctoral fellow, based at the Carnegie Institution for Science's Department of Terrestrial Magnetism, in Washington, DC. I applied for the position shortly after finishing my PhD, in which I studied the evolution of giant volcanoes on Mars using GIS techniques to map landforms on their flanks. My experience with Esri ArcGIS and the use of two- and three-dimensional image and topographic data was definitely a boon to my getting hired by the MESSENGER team because I had the training and background to combine the types of data we were going to get of Mercury. From the start, the mission placed a large focus on using GIS to analyze and make sense of what we were seeing on Mercury. All the data we downlink were, after some processing, made GIS ready, and so it was a fairly straightforward task to drop it into ArcMap and get mapping!

DeMeritt: In the fall 2012 *ArcNews* article "Surveying Mercury" *[written as MESSENGER was sending the first image data back to earth]*, you said that cartography was pretty much the most important way to interpret the geology of any planetary body. What are the most significant discoveries that MESSENGER has made, and how do they illuminate our models of terrestrial planet formation, if at all?

Byrne: We've had such a successful mission with MESSENGER that it's impossible to say which one discovery is the most important. There have been so many. For example, MESSENGER data have been used to produce maps of so-called permanently shadowed craters—craters near the poles in which sunlight literally never reaches the crater floors. Inside many of these craters, MESSENGER spectrometer, altimeter, and image data together show that not only are there deposits of organic, volatile compounds present but also deposits of water ice. We've even been able to directly image some of these exposed ice deposits. That ice had been identified from radar measurements taken from Earth long before MESSENGER and had even been hypothesized to be water ice, but to confirm that hypothesis with multiple datasets was a major achievement of MESSENGER's mission.

DeMeritt: To what extent did the maps generated from Mariner 10 spacecraft—the first probe to visit Mercury—inform the mission?

Byrne: We'd be remiss to ignore what Mariner 10 told us about Mercury, even if that mission was completed four decades ago. Mariner 10 only saw about one-half of Mercury's surface in its three flybys in 1974–1975, but that half was enough to calibrate our understanding of the planet and frame the questions that MESSENGER was designed to answer.

DeMeritt: Was GIS used to extrapolate information from those old maps?

Byrne: Absolutely. The United States Geological Survey has done a wonderful job converting Mariner 10 data to a GIS-compatible format, which means we can make direct comparisons between MESSENGER and Mariner 10 data within the ArcGIS environment seamlessly. We've been able to start with the Mariner 10 quadrangles *[slightly overlapping rectangular maps of a planetary surface established by the US Geological Survey that cover 7.5 minutes of latitude and 7.5 minutes of longitude]* and compare them with imagery from MESSENGER. That comparison enabled scientists to look for geological units, landforms, and so forth, in areas that Mariner 10 didn't see—basically the whole northern hemisphere. We did this to answer the question of whether what we saw in that one hemisphere in the 1970s is representative of the planet as a whole. It turns out that, in the main, this is the case.

Mariner 10 data have also helped us understand how best to produce geological maps of Mercury. The different quadrangles published after the Mariner 10 mission weren't always entirely consistent with each other: the boundaries between different geological units might change location from one quadrangle to another or disappear between neighboring quadrangles entirely. MESSENGER team members are currently developing a new, global geological map with MESSENGER data, incorporating the lessons we can learn from earlier mapping with Mariner 10 images. All of this analysis takes place within GIS.

DeMeritt: The Mariner 10 flybys of Mercury in the 1970s showed what looked like buckles on the surface, seemingly indicating that it shrank over time. Was one of the objectives of MESSENGER to measure the contraction with a more detailed basemap?

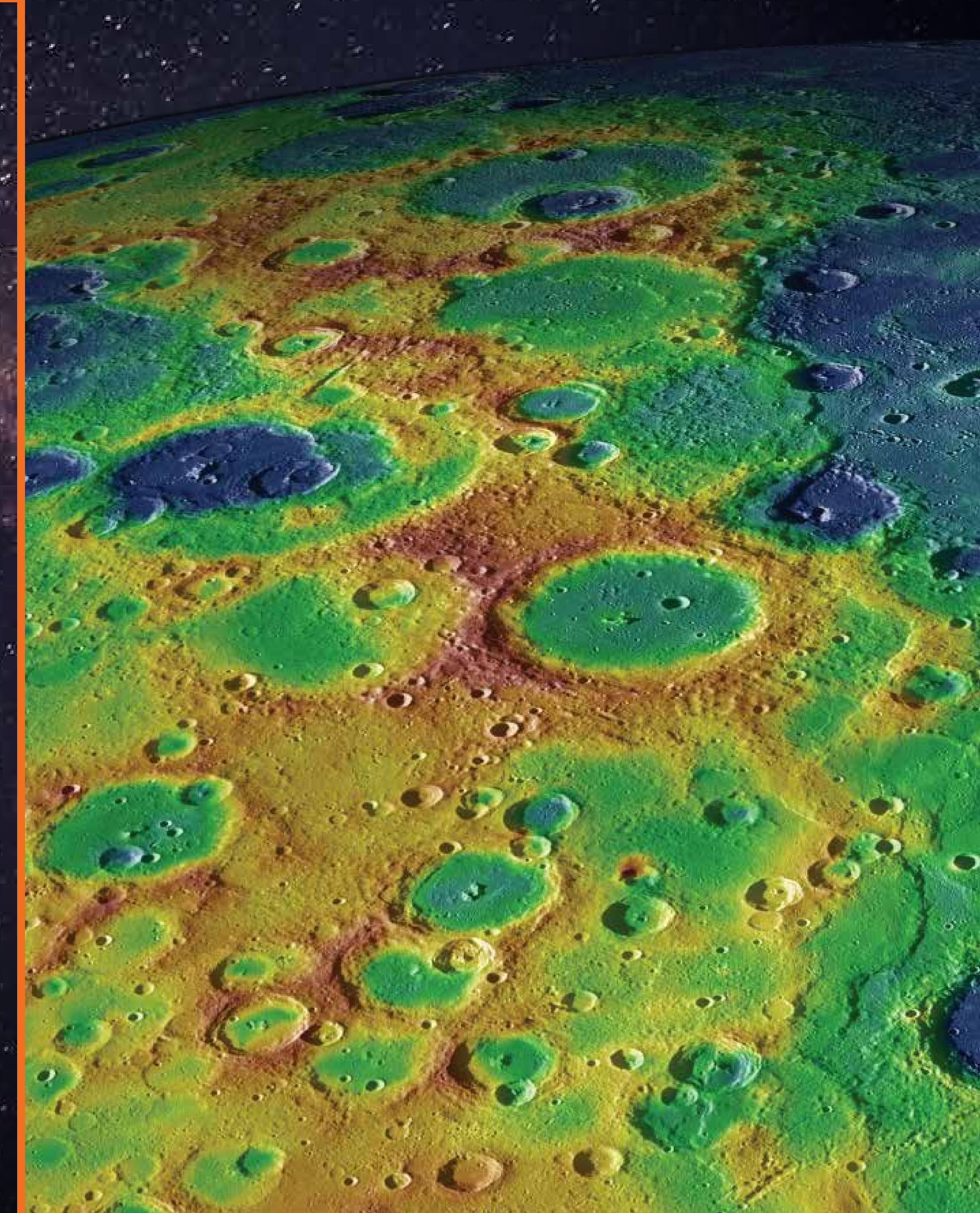
Byrne: Yes. One of the big questions raised by the Mariner 10 mission was, Are the cliff-like scarps we see in abundance on one-half of the planet also on the other half? Mariner 10 only observed Mercury's southern hemisphere. Determining the amount that Mercury contracted tells us a lot about its interior structure and volcanic history. We used photogeological images to first map the lengths and characterize the distributions of these scarps across the entire surface using the Editor tools within ArcMap. We could then add topographic data to the project and use the *[ArcGIS]* 3D Analyst extension to determine the topographic profile of a subset of these mapped scarps.

With that information, together with some basic statistical assumptions about the geometry of faults underlying these scarps, we were able to calculate the extent to which Mercury had contracted. We were pleasantly surprised when we found that Mercury has shrunk in radius by as much as 7 kilometers, which is the biggest global contraction of any terrestrial body we've observed in the solar system so far.

With those same basemaps, the oldest parts of Mercury have been identified on the basis of the number of impact craters per a given surface area; strangely, the oldest portion of Mercury's crust is about 4.1 billion years old, but the planet as a whole is the same age as Earth: 4.56 billion years. There's over 400 million years of missing history on Mercury, and we're still working to figure out why it went missing.

On the other hand, it turns out that Mercury has some staggeringly young features too. MESSENGER image data have told us a lot more about strange pit-like landforms we call "hollows" appearing all over the planet. Hollows appear to be sites where something has sublimated from the planet's surface, but just what that material is remains an open question. From our global mapping and high-resolution targeted images, we now know the distribution, sizes, shapes, and even the rates of formation of these unique landforms.

In short, the image data alone from MESSENGER will keep us occupied for many years to come, at least until the European Space Agency's BepiColombo mission reaches the planet in 2024, and probably for a long time thereafter. And given that MESSENGER is one of NASA's Discovery-class missions—the cheapest of three mission classes—our new understanding of the innermost planet has come at a bargain price.

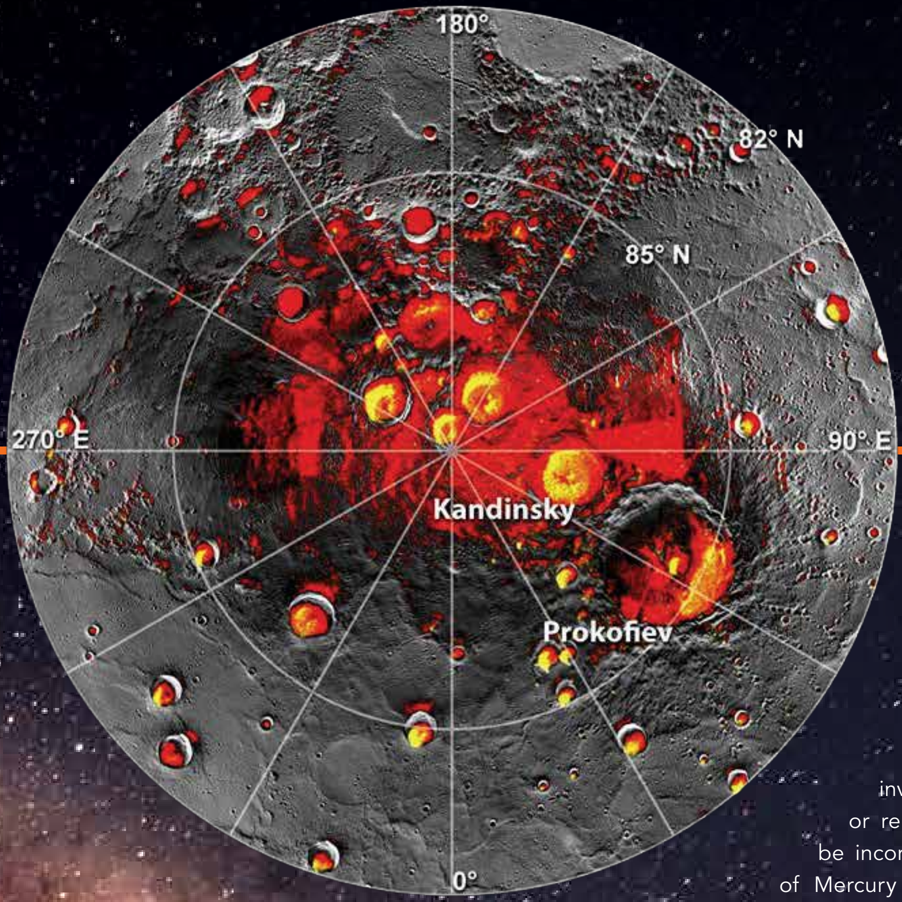


Mercury's surface with elevations color-coded from high to low terrain. A series of cliff-like scarps along the right-hand side of the image form what scientists term a "fold and thrust belt." Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/ Carnegie Institution of Washington.

DeMeritt: Some laypeople might look at Mercury and not see much difference between it and our moon. Do maps of Mercury give us any insight into the larger questions about planet formation relative to location in the solar system?

Byrne: The majority of Mercury's surface is composed of solidified lavas that have been substantially reworked by subsequent asteroid impacts, whereas most of the lunar surface is made up of a material that formed very early in the moon's development and is chemically very different from Mercury's lavas. We can make these comparisons because we have enormous volumes of chemical data for Mercury, which we can plot into global elemental abundance maps, for instance. And from measuring the number of craters per unit area on both Mercury and the moon, we can tell that, although lavas poured onto the surface of the moon over several billion years, the resurfacing of Mercury by lavas ended globally at around the same time, almost four billion years ago. MESSENGER scientists are still working to figure out why, but it may be a result of the planet starting to cool and contract, which squeezed shut the conduits that magmas were able to exploit on their way to the surface.

Some of the MESSENGER mission's fundamental objectives included understanding Mercury's geological history, the nature of volatile materials at the poles, and the composition of the planet's surface. Integrating imagery, chemical, spectral, and geophysical data, among other types of data, has afforded us the ability to answer those questions and raise a whole host of new ones. It's no exaggeration to say that the MESSENGER mission has been a resounding success, but it's also a teachable moment about one of the fundamental aspects of scientific exploration: once we go out there, we'd better be prepared to go back because with every question we answer, we'll ask two more questions. That's as true for Mercury now as it was after we first visited it in the '70s—we know so much about the innermost planet, but we also know we have a lot more yet to go.

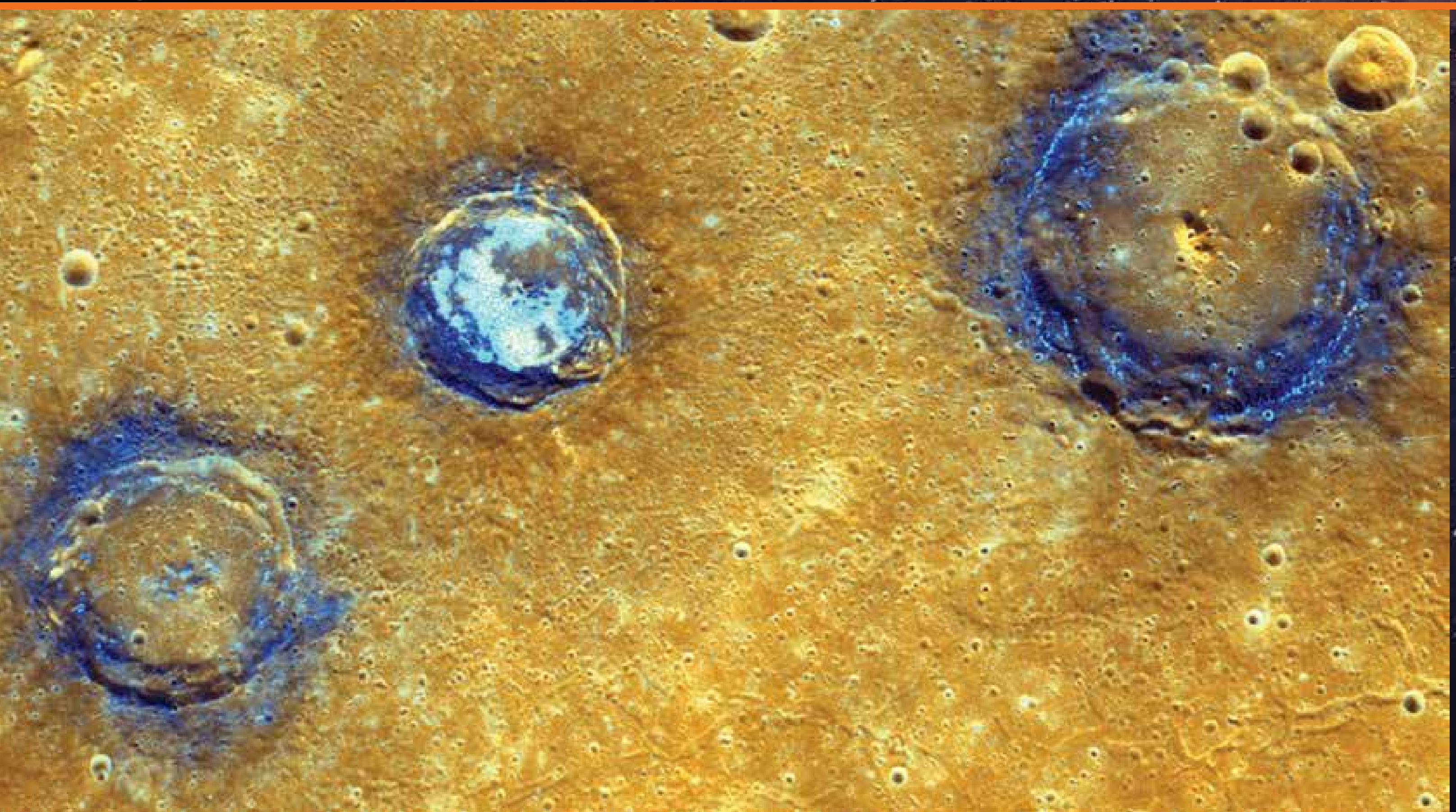


A map of permanently shadowed regions and radar-bright polar deposits in the northern polar region of Mercury. MESSENGER data has shown that the radar-bright deposits are composed of water ice, sometimes beneath a lag of organic material. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

DeMeritt: How important is stereo imagery in studying Mercury's landforms?

Byrne: Geology itself is manifest in 3D, so investigating any geological body, process, or relationship requires that the third dimension be incorporated. Being able to explore the surface of Mercury with topographic data, whether obtained through stereophotogrammetry or through interpolation of altimetry data, represents a powerful advantage in our quest to understand the planet's geology and history. Digital elevation models *[DEMs]* have, for instance, been used to quantify large-scale topographic warps in the planet's lithosphere, the origin of which we still don't fully understand. And topographic data can tell us the thicknesses of lava flows in impact craters, the depths of explosive volcanic vents, and even the large-scale shape of the planet. Without these data, our understanding of Mercury would be much poorer.

Since all MESSENGER data—indeed, data from all NASA missions that can be analyzed in GIS—are published in an ArcGIS-compatible format, the Spatial Analyst and 3D Analyst extensions for ArcGIS for Desktop's ArcMap application are our go-to tools for exploring topographic data. We can also use ArcScene and even ArcGlobe to visualize subtle variations in relief, investigate relationships, or even vertically exaggerate the landscape of DEMs produced from MESSENGER imagery and altimetry data. A personal favorite of mine is to use the ArcToolbox Conversion tool to export various ArcMap layers to KML files for visualization in Google Earth. That's a very powerful instrument for scientific analysis, conference presentation, and educational outreach.



This enhanced color mosaic shows (from left to right) Munch, Sander, and Poe craters, which lie in the northwest portion of the Caloris basin. The smooth volcanic plains that fill the Caloris basin appear orange in this image. All three craters are superposed on these volcanic plains and have excavated low-reflectance material, which appears blue in this image. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

DeMeritt: What would be your dream GIS for investigating planetary geology?

Byrne: Processing and analyzing topographic data must underpin any mission in which we gather knowledge about a planetary body's geology, whether that's from an orbiter, lander, or rover. Flying uncrewed aerial systems through the atmospheres of Venus or Mars, say, or remotely operating a boat on the lakes of Titan would be enhanced by high-resolution topographic data. So, my dream GIS would be a fully immersive GIS technology. Virtual reality software and hardware would enable almost fieldwork-scale investigation of planetary surfaces. That would be a major step in science education and outreach and even in preparing astronauts for on-the-ground work on the moon or Mars!

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