GIS Best Practices

# Spatial Data Infrastructure (SDI)

September 2010

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# What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

# What Is SDI?

Social challenges, environmental issues, and economic downturns all take cooperation to solve. Working together to map and document the earth helps create a structure for managing knowledge. Using GIS solutions from Esri to create a spatial data infrastructure (SDI) ensures that data and resources are available to the organizations and stakeholders that need them. From large countries to small nations, everyone benefits from documented public works and utilities, protected environments and biodiversity, correctly assessed resources, and completed strategic planning.

The term *spatial data infrastructure* was coined in 1993 by the U.S. National Research Council to denote a framework of technologies, policies, and institutional arrangements that together facilitate the creation, exchange, and use of geospatial data and related information resources across an information-sharing community. Such a framework can be implemented narrowly to enable the sharing of geospatial information within an organization or more broadly for use at a national, regional, or global level. In all cases, an SDI will provide an institutionally sanctioned, automated means for posting, discovering, evaluating, and exchanging geospatial information by participating information producers and users.

SDI extends a GIS by ensuring that geospatial data and standards are used to create authoritative datasets and polices that support it.

# Economic Growth Strategy Transformed Through a Spatial Data Infrastructure

## *Croatia Simplifies Landownership Process with a National Geoportal*

Highlights

- The ArcGIS Server Geoportal extension is improving land reform.
- With ArcGIS Server, ministries quickly access geospatial resources of all types.
- Croatian GIS users now have access to vast quantities of geospatial data.

The Republic of Croatia, roughly the size of West Virginia, is home to more than 4.4 million people. Ranked as the 18th most popular tourist destination in the world, sightseers visit its beautiful national parks, the high peaks of the Dinaric Alps, and more than 1,000 islands in the temperate Adriatic Sea.

*A view over the old city walls of Dubrovnik, Croatia, and its old harbor.*

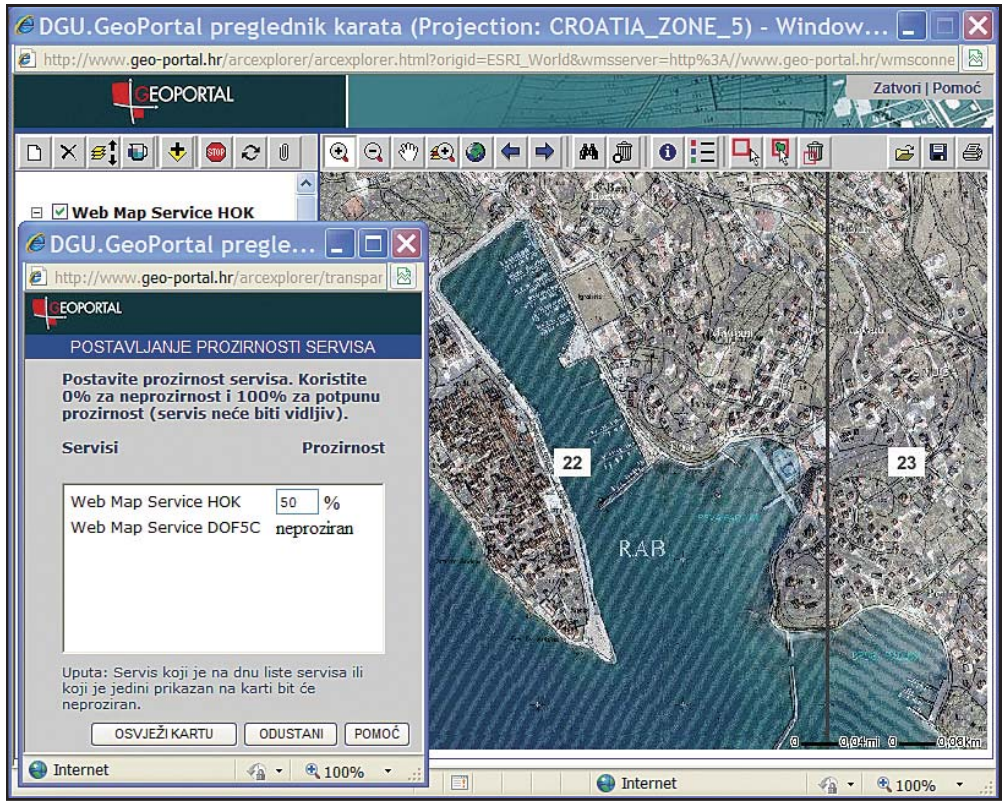
A successor state of the former Yugoslavia, the country declared its independence in 1991, which the European Union (EU) and the United Nations recognized in 1992. Building itself up from virtually nothing, the country is now governed by a forward-thinking parliamentary republic, which is adopting new laws to promote economic growth and help its candidacy for EU membership.

Making countrywide geographic data available throughout the nation with a spatial data infrastructure (SDI) is one way the country continues to grow. An online geoportal created with GIS technology makes this possible. The geoportal makes it easier for citizens, government, and private-sector users to find and access vast quantities of geographic information and related services. The geoportal is the first phase of a Croatian national SDI and has already shown its value by reducing the time it takes to register land within the country by 90 percent.

## Enabling Property Rights in Croatia

Ten years ago, a simple land title transaction took an average of 400 days to carry out. Most information was stored and managed in paper-based files, making it difficult to share. Agencies, such as the State Geodetic Administration (SGA) in charge of the country's official maps and cadastre, and the Ministry of Justice, responsible for land registers issued at municipal courts, could not easily exchange data.

In 2000, the Croatian Parliament adopted a State Survey and Real Property Cadastre Program to transform the existing registers into digital format. This involved topographic surveys as well as resurveying 5 percent of the existing cadastre focusing on areas of special interest, such as towns, coastlines, islands, nonregulated state agricultural land, and infrastructure corridors.




*As the first step toward an SDI, the cadastral data managed by SGA is now available for browsing, searching, and purchasing via an online data catalog found at www.geo-portal.hr/Portal.*

The datasets were cofinanced by federal institutions and interested local governing bodies. For example, orthophoto production was completed through 30 different agreements between local and state governments. Over a 10-year period, 21 counties produced topographic data and resurveyed each cadastre. By the end of 2010, 56,000 cadastral maps will be digitized and verified.

Once created, the data is gathered and housed in the Real Property Registration and Cadastre Joint Information System (JIS). The JIS unites the cadastral data managed by SGA and legal information from the Ministry of Justice. Having consistent and shareable data across the country via the ArcGIS Server Geoportal extension is improving the processes of implementing land reform because documents can be issued from both cadastre and land registers. The average time for processing changes to land titles has dropped from a 400-day average to less than 37 days.

## Online Data Access Through Geoportal

As the first step toward an SDI, the cadastral data managed by SGA is now available for browsing, searching, and purchasing via an online data catalog found at www.geo-portal.hr/Portal. To develop the geoportal, the state selected Esri's distributor in Croatia, GISDATA d.o.o., and con terra GmbH, the professional services arm of ESRI Deutschland GmbH, Esri's distributor in Germany and Switzerland. The companies established an action plan to develop a national SDI. They chose ArcGIS Server and the ArcGIS Server Geoportal extension to provide the platform for the state's ministries to quickly access geospatial resources regardless of location or type.

Based on the EU's Infrastructure for Spatial Information in Europe (INSPIRE) directives for sharing geographic information across Europe, Croatia's national SDI will provide a more open, transparent, and efficient use of spatial information, as seen through the improved land registration.

SGA registers data with the geoportal by using metadata, which follows the ISO standards required by INSPIRE. Only the metadata is uploaded to the geoportal, while SGA's sensitive data remains securely housed within its own servers. Through the ArcGIS Server Geoportal extension, registered data includes digital orthophotos, 1:5,000-scale basemap information, raster cadastral maps, administrative units through the Central Registry of Spatial Units, and land survey information from the Registry of Geodetic Points.


*SGA provides the platform for organizations to quickly access geospatial resources regardless of location or type.*

## The First Step to a National SDI

By the end of the year, more agencies within Croatia will register their data with the geoportal, using the SGA data as a guide for resolution and standards. The Ministry of Defense; the Ministry of Culture; and the Ministry of Agriculture, Fisheries, and Rural Development will all provide spatial data.

By creating a comprehensive SDI, Croatia expects to continue to see improvements in the reduction of time when producing and accessing data. Geospatial data and service producers in the government will be easily connected to the consumers who need the data. Data integrity will be maintained, and the users can more easily share the authoritative version of data.

Dr. Zeljko Bacic, director general of SGA, says, "Simple access to geospatial data is the key prerequisite for an efficient and economically prosperous society. A geoportal in operation means that other governmental organizations can use SGA data but also make their data accessible. This is the first step to the establishment of a Croatian national geoportal as part of a national SDI. I am convinced we shall do this soon, as we have a clear direction from the Croatian government and sufficient knowledge and capacity to do this."

The SGA geoportal has revealed opportunities in local and regional government for GIS users in nature protection, urban planning, agriculture, public safety, and more. "The SGA geoportal is the first of its kind in southeastern Europe," says Andrej Loncaric, director of GISDATA in Croatia and the southeastern region. "Croatian GIS users now have access to vast quantities of geospatial data that will make their everyday work much easier."

(Reprinted from the Summer 2010 issue of *ArcNews* magazine)

# Collaboration Through GIS and a Regional SDI

## *GeoSUR Opens Geographic Information for Use Throughout South America*

Highlights

- The GeoSUR Regional Map Service was developed with the support of the EROS Center using ArcGIS Server.
- The ArcGIS Server Geoportal extension provides quick access to geospatial resources throughout the region.
- GeoSUR offers a cutting-edge, on-the-fly topographic processing service.

Sustainable development means meeting the needs of the present while preserving the environment for future generations. Creating an economy in a country that is in tune with basic ecological support systems doesn't stop at country borders. Rivers traverse borders, roads must connect various cities, and forests transcend country boundaries.

South America, with its bountiful natural resources, will benefit from a collaborative effort to manage its many precious resources and maintain healthy living conditions for its people. "There is a need in South America to make important development decisions—decisions that impact the lives of thousands, sometimes millions of people—using sound and accurate scientific information," says Eric van Praag, regional coordinator of the GeoSUR Program. "Much of this information can be expressed geographically and can be put into formats and represented in ways that decision makers understand and can readily use."

Ensuring that geographic information is readily available is the mission of the GeoSUR Program, a regional initiative to integrate and disseminate spatial data in South America. GeoSUR was originally developed under the aegis of the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), which promotes the development of transportation, energy, and telecommunications infrastructure from a regional viewpoint. Since the program's inception in 2007, GeoSUR has grown to serve a large audience interested in development objectives, both regionally and within individual countries.

GeoSUR has three main components: a geoportal, a network of map services, and a regional topographic processing service.


*GeoSUR serves an audience interested in regional development objectives on the continent of South America.*

## GeoSUR Portal Makes Updating and Finding Spatial Data Easier

GeoSUR has developed, with support from the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, the first regional portal providing access to geographic data and services from all South American countries (www.geosur.info). Launched in October 2009, it provides a point of entry to the map services and metadata catalogs operated by GeoSUR's partner agencies. GeoSUR chose the ArcGIS Server Geoportal extension software to build the portal because it provides an efficient platform to integrate the diverse and changing geospatial resources located throughout the region.


*GeoSUR portal home page.*

The regional portal provides access to the metadata holdings of all the participating agencies. It keeps a central metadata database that is periodically updated by an automatic harvesting mechanism that fetches metadata from the participating agency's catalogs. The portal also contains a map viewer that allows the user to retrieve, open, and view layers available in partner map services. The network architecture is decentralized to keep the data updated and close to its producers. Currently, there are more than 20 map services linked to the portal and more than 3,000 metadata records available on its database.

## Network of Regional and National Map Services

A great variety of national and regional spatial data is available through GeoSUR, including political-administrative divisions, soils, topography, ecosystems, hydrography, biodiversity, water bodies, geology, cities and towns, elevation models, land cover, aerial photos, ecological regions, satellite imagery, and infrastructure.

This information is available through a decentralized network of map services currently being created by the GeoSUR participating agencies, with each agency committing to the development of a Web Map Service (WMS) and a metadata catalog. Once a map service is developed, the map service administrator creates an ISO 19119 metadata record for it and registers it on the GeoSUR portal for public viewing.

GeoSUR emphasizes the use of recognized Open Geospatial Consortium, Inc. (OGC), and International Organization for Standardization (ISO) standards and protocols to reach interoperability of its various geoservices. Participating agencies have the liberty of choosing the hardware and software platforms for sharing data with the network, provided they use regionally recognized standards.

Most map services in the network contain geographic data at the national level, but there are two regional services available today: the GeoSUR Regional Map Service and the Condor Service.

The GeoSUR Regional Map Service is geared toward infrastructure developers, offering access to spatial data on existing IIRSA and Andean Development Bank (CAF) infrastructure projects and on themes that impact infrastructure development, such as roads, ports, airports, railroads, oil pipes, rivers, protected areas, land use and land cover, and topographic relief. The service was developed with the support of the EROS Center using ArcGIS Server. All regional data in the service is available for download at no cost.

The Condor Service allows visitors to view environmental data of the Andean countries useful for planning infrastructure projects. The service includes an early assessment tool focused on identifying environmental risks and opportunities for projects in the planning phase. The Condor map viewer is available at esriurl.com/c3.

## On-the-Fly Topographic Processing Service

GeoSUR offers a Topographic Processing Service (TPS), the first of its kind in the developing world that provides access to digital elevation model (DEM)-derivative products that can be generated on the fly for any location in South America. Users can run the service models using an assorted set of DEMs at different resolutions, including 1 kilometer, 90 meters, and 30 meters. The available TPS models include elevation profile, slope classification, dynamic watershed delineation, hillshade, elevation classification, aspect, and raindrop trace. The service is part of the GeoSUR Regional Map Service, available at the GeoSUR portal (www.geosur.info). All TPS-derived data can be downloaded free of cost.

Before launching the service, the USGS EROS Center filled the voids in the Shuttle Radar Topography Mission (SRTM) 30-meter dataset for South America with Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) GDEM and GTOPO30 data and created a set of seamless derived datasets that include hillshade, shaded relief, slope, and aspect for the region.

Advanced users can directly access these models from ArcGIS Desktop by accessing the TPS GIS geoprocessing service. From within ArcMap, local data can be used with this service to more precisely extract the derivative products and simply integrate them into the application. To further streamline the TPS service, users can integrate them in local ModelBuilder applications and Python scripts.

"Important development decisions are often taken without the proper use of geographic information and modeling techniques that are now becoming widely available," says Santiago Borrero, secretary general of the Panamerican Institute of Geography and History (PAIGH).

## GeoSUR: An Eye on Spatial Data for South America

GeoSUR is coordinated by CAF and PAIGH, with technical assistance from the USGS EROS Center and the national mapping agencies of Colombia, Chile, and Ecuador. Participating agencies include, but are not limited to, national geographic institutes and national environmental agencies from the region. In total, more than 22 national agencies have agreed to participate in the GeoSUR Program, with more expected to join.

GeoSUR provides training and technical assistance to all partner agencies as they develop the map services and metadata catalogs to be linked to the GeoSUR Geoportal and the Regional Map Service. GeoSUR specialists are on call to offer technical assistance that agencies may need, both remotely and on-site. GeoSUR also sponsors peer-to-peer communications among participating specialists.

## More Information

For more information, visit www.geosur.info.

(Reprinted from the Summer 2010 issue of *ArcNews* magazine)

# Abu Dhabi SDI Supports Wide-Ranging E-government Programs Using GIS

Highlights

- The operations team uses GIS for data processing, data review and assessment, and publication of map services.
- ArcGIS Server and ArcGIS Mobile solutions aid in developing the AD-SDI clearinghouse and associated metadata catalog.
- The AD-SDI geoportal provides access to the data clearinghouse from which more than 300 map layers are being made available to the community.

Abu Dhabi, the capital of the United Arab Emirates (UAE), lies on a T-shaped island jutting into the Persian Gulf. Today, Abu Dhabi houses key sustainable energy, economic, and environmental initiatives leveraging leading technology. As such, the timely collection, preservation, and distribution of relevant geospatial data are critical to maintain its spatial data infrastructure and ensure the smooth running of the emirate's many governmental and commercial activities.

The Abu Dhabi Spatial Data Infrastructure (AD-SDI) is an initiative administered within the Abu Dhabi Systems and Information Centre (ADSIC) to facilitate the sharing of geospatial data among government agencies and other stakeholders. As part of Abu Dhabi's ambitious e-government program, AD-SDI is empowering government and society with convenient, open access to high-quality and up-to-date geographic information and spatially enabled e-government services.

In Abu Dhabi, government entities have invested heavily in GIS technology and geospatial data to meet their own organizational needs. The emirate is now in an excellent position to leverage that investment by establishing the necessary institutional capabilities that are needed to support more effective sharing and utilization of geospatial information. AD-SDI was conceived to provide that framework.

*A satellite image of Yas Island (IKONOS 2009 one-meter imagery courtesy of Space Reconnaissance Center).*

## Establishing the AD-SDI Initiative

In June 2007, ADSIC launched the AD-SDI initiative to provide a framework of standards, policies, data, procedures, technology, and capable staff to facilitate and support the effective use and sharing of geospatial information in Abu Dhabi. Incorporated into AD-SDI are a data clearinghouse, geospatial portal, and Web site, as well as an extensive program for community engagement, organization, coordination, and establishment of formal agreements for data provision and sharing.

The operations team at the Spatial Data Center (SDC) is utilizing the ArcGIS suite of software for data processing, data review and assessment, publication of map services, and GIS analysis and cartography for special projects. Esri technology has also been used in developing the AD-SDI clearinghouse and associated metadata catalog and the supporting services based on ArcGIS Server technology and the REST and SOAP interfaces, in addition to mobile GIS applications based on the ArcGIS Mobile solution. Other map viewers were built using Flex and Java APIs.

A dedicated AD-SDI staff is in place to facilitate, promote, coordinate, and support the AD-SDI initiative with the various member entities. Venues for such cooperation and collaboration with entities include facilitating the AD-SDI Technical Committee meetings and discussions; developing and implementing agreed-upon standards for geospatial data maintenance and update; and mobilizing working groups and special interest groups in key areas of common interest, such as environment, utilities, and public safety and security.

Now in the third stage of a three-stage process, the initiative has almost 40 government and quasi-government entities involved, with more expected to join this year. As part of the community development, ADSIC is in the process of developing service-level agreements and licensing arrangements with each entity that spell out what data will be provided, the timing of periodic updates, and access and use restrictions for the data each is providing. In addition, a geolegal policy has been mobilized to work on strengthening aspects of the legal framework to address issues that have special relevance to geospatial matters, such as security, privacy, and intellectual property rights.

## Standardization Essential in AD-SDI Development

Standards including the appropriate data, technology, and procedures are essential to ensure interoperability across the AD-SDI community.

*Abu Dhabi large-scale basemap (courtesy of Department of Municipal Affairs-Abu Dhabi Municipality).*

Integrating existing GIS data and procedures across the AD-SDI community is a matter of proactive stakeholder engagement and consultation to avoid redundant and often inconsistent spatial datasets. Today, the emirate's fundamental geospatial datasets (FGDS), such as cadastral data, orthoimagery, elevation data, transportation, land use, soils, and utility networks, are maintained by the relevant government organizations. The entities are streamlining their workflow to update the spatial data they are responsible for by recording changes on the ground as they occur as part of their business processes. This approach of transaction-based data maintenance ensures that spatial data is updated and delivered to the AD-SDI community in a timely manner.

A geospatial metadata catalog is another significant factor in maintaining standardization in AD-SDI, as it provides a master inventory of the fundamental data and geospatial services available. All the layers in the data clearinghouse have some level of metadata that is accessible through the geoportal. The metadata catalog was originally compiled by the ADSIC team, but responsibility for maintenance of this information is being transferred to the custodian agencies as a condition within the service-level agreements. Organizations using Esri products can maintain their data through ArcGIS Desktop. Others can update their information through the geoportal, once authorized to do so, or through any ISO standards-based metadata maintenance tool.

## Geoportal Key to AD-SDI Success

The ultimate goal of the AD-SDI initiative is to create a seamless network of interoperable nodes—geospatial portals—that will provide easy access to all geospatial information in the emirate. Currently, both secure government and publicly accessible geoportals have been set up, and the information available is being expanded and updated on an ongoing basis.

The AD-SDI geoportal provides access to the data clearinghouse from which more than 300 map layers are being made available to the community. Data is now being kept current, as the custodian entities periodically submit updates to the ADSIC team, which runs the data through procedures to ensure that the new information is consistent with the agreed-upon standards. The geoportal is being used as a common reference for viewing existing data, and a few users are now employing thick-client access to map services.

Many organizations in the AD-SDI community have implemented or are planning to implement their own geoportal nodes. The Environment Agency-Abu Dhabi has been operating its node for over two years, and other entities, such as the Abu Dhabi Water and Electricity Authority, Department of Municipal Affairs, and Urban Planning Council, have instituted or are planning to institute their own Web-based mapping services for internal and public use.

## AD-SDI Garners Wide Support and Boosts Potential Savings

The essential value of AD-SDI is widely recognized across the community, and huge cost savings are already being realized in several ways:

- All spatial data maintained by organizations for their own business purposes is now standardized according to the broader needs of the community, leading to improved and newer usages of the data, thereby leveraging the value of the data investment many times over.

- Previously, spatial data projects could be launched by individual government entities. Now, the AD-SDI Technical Committee is included in the procedure, which leads to better alignment of the projects for the common needs of the community and avoids costly and redundant data acquisition.
- The top leadership is now being provided with access to accurate and up-to-date information in a reliable and timely manner, empowering it to make informed decisions.

The implementation of these portals will lead to a greater sharing and utilization of spatial data in Abu Dhabi. The participating organizations are now routinely adding new users as more people become aware of what is available and how it can be used in their work.

## More Information

For more information, contact the Abu Dhabi Spatial Data Infrastructure initiative (e-mail: info.sdi@adsic.abudhabi.ae) or visit www.sdi.abudhabi.ae.

(Reprinted from the Summer 2010 issue of *ArcNews* magazine)

# Austria's Geographic Data Conforms to INSPIRE

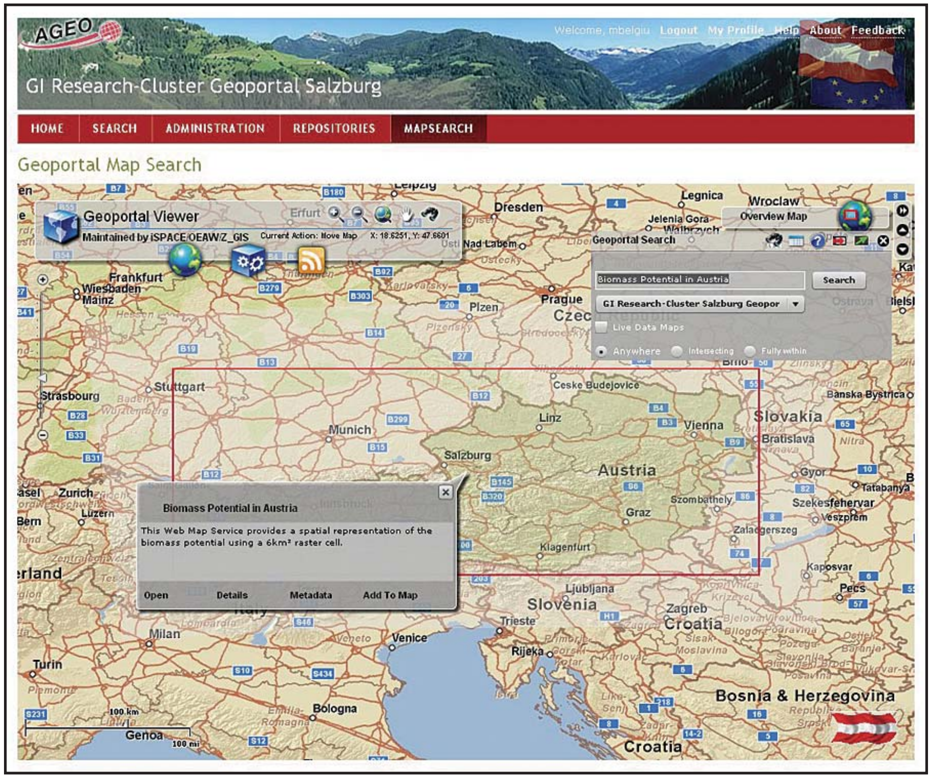
By Mariana Belgiu, Research Assistant, Austrian Academy of Sciences, Institute for Geographic Information Science

Highlights

- ArcGIS Server Geoportal extension supports customized metadata profiles.
- Geographic information custodians can publish metadata that conforms to the Austrian Metadata Profile.
- Information sharing helps private- and public-sector agencies reap the benefits of working together.

Austria encompasses much of the mountainous territory of the eastern Alps, which contains many snowfields, glaciers, and snowcapped peaks. Nestled in valleys near idyllic farms and hidden among the forests and woodlands that cover almost half the land lie glistening palaces and gabled houses.

To protect the beauty and splendor of its natural resources, Austria has used GIS for the past 25 years. The Federal Office for Metrology and Surveying maintains geoinformation on a national level. However, Austria consists of nine independent federal states, each with its own provincial government, which has led to the creation and management of geographic resources being scattered across many organizations. Having disparate data sources makes it difficult to use the information to make more informed decisions on social and environmental issues. To solve this problem, it is necessary to develop a coordinated spatial information system capable of data sharing and reuse on national, regional, and cross-sector scales.




*Visualizing biomass potential in Austria with Web map services.*

The system is a geoportal based on ArcGIS Server and the Geoportal extension. The geoportal gives the states and regions a collaborative approach to developing a coordinated, comprehensive, and sustained information system. The Austrian umbrella organization for geographic information, AGEO, strongly supported the development of the geoportal, as it clearly demonstrates the practical use and value of a metadata management system.

## Coordination Across Austria

AGEO was formed in 1998 to make it easier to access geographic data throughout the country. The organization brings together national and municipal administrations, universities, and many different professional associations, representing the interests of the Austrian geographic information community at both the national and international levels.

In the last few years, this umbrella organization has focused its activities on supporting and promoting the development of a national spatial data infrastructure within the framework of a European geographic information-sharing community. "The AGEO organization is concentrating its activity not only on public administration of geographic data but also on business; academic; and, of course, general public interests," says Prof. Dr. Josef Strobl, the current chair of AGEO.

At the European level, the European Commission, the Council of the European Union, and the European Parliament set up the legal framework for developing the Infrastructure for Spatial Information in Europe, the INSPIRE Directive. This directive (Directive 2007/2/EC) came into force in May 2007 and aims to integrate islands of geographic information of varying standards and quality throughout Europe. Austria incorporated the INSPIRE Directive into its national legislation, taking a first step toward implementing the requirements of the directive in the country. The next step involves the creation of communication mechanisms between producers and users of the geographic information.

## Metadata Makes Sharing Geographic Information Easier

One of the main difficulties with sharing data in Austria is that the available spatial datasets and services lack comprehensible documentation. This can be solved by accompanying the spatial data with metadata, which is structured information that describes the datasets. Unfortunately, many data producers do not understand the benefits of creating metadata and treat the task as boring, time consuming, and therefore unnecessary.

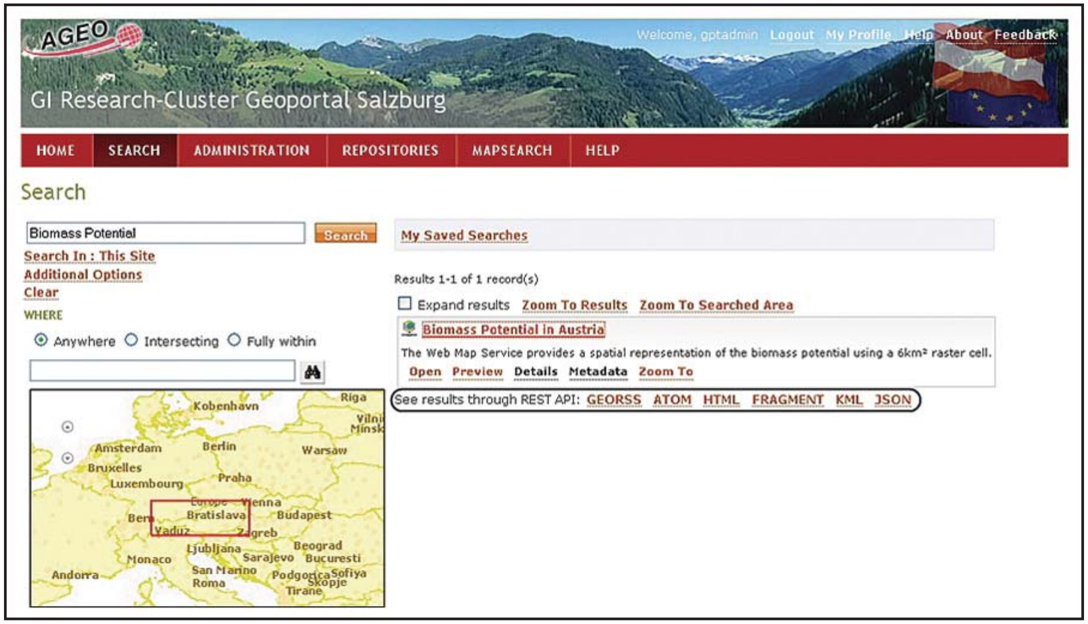
To address this problem, Austria prepared a national metadata profile combining specifications of international standards, INSPIRE's Metadata Implementing Rule, and existing regulations in the country. This profile, the Austrian Metadata Profile (profil.AT), ensures a consistent approach to geographic information throughout the country. It specifies the metadata elements needed to increase the lifetime and value of spatial data and services. These elements include identification information; use restrictions; spatial and temporal extent; geographic resource maintenance information; spatial representation and reference; quality; and the distribution of geographic resources, such as access policies.

The Geoportal extension provides data publishers with an online metadata editor that makes it easy for them to publish metadata about geographic resources in conformance with the Austrian Metadata Profile. The Geoportal extension was chosen because it provides the technological keys for sharing and reusing resources across applications, enterprises, and community boundaries and facilitates development of a metadata editor that conforms to a specific metadata profile. The Geoportal extension also includes a metadata editor tool, discovery tools, a data visualization application, and metadata harvesting tool that enable automated acquisition of metadata from other repositories.

## Bridging Data Producers and Users

The geoportal represents the bridge between data producers and users. The producers create data and services for their own business needs and publish corresponding metadata to the geoportal. Users formulate queries and evaluate the returned metadata records to decide whether the discovered data accomplishes their requirements.

The geoportal's metadata editor makes geographic resources discoverable in a straightforward manner. The publisher logs in to the geoportal and chooses either the spatial datasets or spatial services schema that conforms to the specifications of the Austrian Metadata Profile. Then, using the metadata editor, the user fills in information about the data or services to create its metadata. If the user needs assistance, hints provide more information about what values should be input in each field. The generated metadata is then added to a metadata repository that is comparable to a library catalog. Users can search and find information about the availability of a particular dataset or service, which includes information about content, author, year of publication, and more.




*Geoportal search for biomass potential.*

The available geoportal and the online customized metadata editor represent an important step toward shaping a national spatial data infrastructure and a milestone toward achieving the goals of the INSPIRE Directive.

## About the Author

Mariana Belgiu is research assistant at the Austrian Academy of Sciences, Institute for Geographic Information Science, Salzburg, Austria. She received her M.Sc. degree in GIS at the University of Salzburg, Austria (2009), and she is now in the initial stages of her Ph.D. work with a focus on ontologies within the spatial data infrastructure framework.

## More Information

For more information, visit the Web site (www.oeaw-giscience.org).

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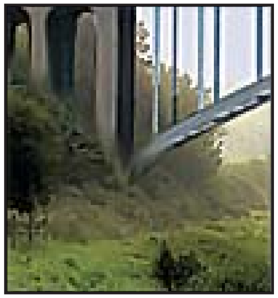
# Building INSPIRE: The Spatial Data Infrastructure for Europe

By Max Craglia, Joint Research Centre of the European Commission

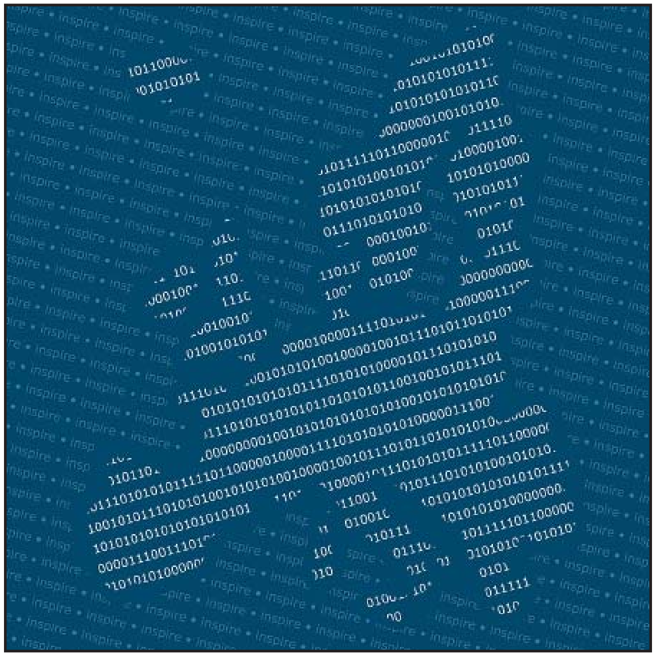
**Disclaimer:** The views expressed in this article are the author's alone and do not necessarily represent those of the Joint Research Centre or the European Commission.



This article is about the European spatial data infrastructure (SDI), which is called, formally, Infrastructure for Spatial Information in Europe, or INSPIRE. Many readers of *ArcNews* will be familiar with the concept of an SDI, as efforts in the United States to develop a National SDI (NSDI) have been under way since the mid-1990s (see also "Governance of the NSDI" by Will Craig in the Fall 2009 issue of *ArcNews*), and many other countries in the world are very active in developing their own. For the readers who are not so familiar with the concept of an SDI, it is easier to think of it as an extension of a desktop GIS. Whilst in a "normal" GIS most of the data we geospatial professionals use for analysis is our own or collected by the agency we work for, an SDI is an Internet-based platform that will make it easier for us to search and find data that may be relevant for our work and that may be collected, stored, or published by other organizations and often other countries. The key components of an SDI are, therefore, catalogues of available resources, documented in a structured way through metadata; agreed-upon access policies and standards; and a set of services to access and download the data to our GIS. In many countries, some key datasets have been identified that are perceived to be of general usefulness to many (the so-called "framework" data in the United States). Priority has therefore been given to documenting them and making them available. Once we have found and downloaded the data we need, we analyze it in our GIS, and finally, we contribute (often but not often enough) to the international pool of knowledge by publishing the results of our analysis so that others can use them.

This, of course, is a rather simplistic perspective. SDIs are children of the Internet, without which they would not exist. They are also the response to an increased recognition that the environmental and social phenomena we are called to understand and govern are very complex, and that no single organization has the know-how and the data to do the job alone Hence, we need to share knowledge and data across multiple organizations in both public and private sectors, and SDIs support this effort.

## INSPIRE



The INSPIRE Directive is a legal act (Directive 2007/2/EC) of the Council of the European Union and the European Parliament setting up an Infrastructure for Spatial Information in Europe based on infrastructures for spatial information established and operated by the 27 Member States of the European Union (EU). For the readers not familiar with the institutional setup of the European Union, it is worth pointing out that the EU is not a federal state but a union of 27 sovereign Member States that agree through a series of international treaties (the latest being the Lisbon Treaty of 2009) to the policy areas in which they wish to share responsibilities and resources (e.g., agricultural, environmental, and regional policies) and those that remain instead the exclusive domain of the national governments (e.g., defense and immigration).

The key decision-making bodies are, therefore, the national governments—represented in the Council with a number of votes proportional to the size of the country—and the European Parliament that is elected by universal suffrage every five years. The European Commission is the civil service body of the EU and has the power of proposing legislation (to the Council and European Parliament) and monitoring its implementation once approved. Not being a federal state also means that there is no equivalent to the U.S. federal agencies in respect to the collection of topographic or demographic data like the United States Geological Survey and the Bureau of the Census. All data comes via the responsible organizations in the Member States. As a result, setting up an EU-wide SDI can only be done in a decentralized way, building on the SDIs and related activities established and maintained by the Member States.

The purpose of INSPIRE is to support environmental policy and overcome major barriers still affecting the availability and accessibility of relevant data. These barriers include

- Inconsistencies in spatial data collection, where spatial data is often missing or incomplete or, alternatively, the same data is collected twice by different organizations
- Lack or incomplete documentation of available spatial data
- Lack of compatibility among spatial datasets that cannot, therefore, be combined with others
- Incompatible SDI initiatives within a Member State that often function only in isolation
- Cultural, institutional, financial, and legal barriers preventing or delaying the sharing of existing spatial data

The key elements of the INSPIRE Directive to overcome these barriers include

- Metadata to describe existing information resources so data can be more easily found and accessed
- Harmonization of key spatial data themes needed to support environmental policies in the European Union
- Agreements on network services and technologies to allow discovery, viewing, and downloading of information resources and access to related services
- Policy agreements on sharing and access, including licensing and charging
- Coordination and monitoring mechanisms

INSPIRE addresses 34 key spatial data themes organized in three groups (or Annexes to the Directive) reflecting different levels of harmonization expected and a staged phasing (see table 1).

The legal framework of INSPIRE has two main levels. At the first, there is the INSPIRE Directive itself, which sets the objectives to be achieved and asks the Member States to pass their own national legislation establishing their SDIs. This mechanism of European plus national legislation allows each country to define its own way to achieve the objectives agreed upon, taking into account its own institutional characteristics and history of development. As an example, Germany does not have a single SDI but a coordinated framework with 17 SDIs, one for each of its states (Länder) and one at the federal level (which also means that 17 different legal acts had to be passed to implement INSPIRE). Similarly, Belgium will have probably three SDIs, one for each of its regions (Wallonia and Flanders) and one for Brussels. The INSPIRE Directive also requires the establishment of an EU geoportal operated by the European Commission to which the infrastructures of the Member States have to connect.

The drawback of having 27 different "flavours" of INSPIRE is that making the system work is undoubtedly more difficult. For this reason, the Directive envisages a second level of legislation, more stringent because it has to be implemented as is and does not require follow-up national legislation. In European terminology, this is called a *regulation.* Therefore, INSPIRE envisages technical implementing rules in the form of regulations for metadata, harmonization of spatial data and services, network services, data and service sharing policies, and monitoring and reporting indicators to evaluate the extent of the Directive's implementation and to assess its impact. Each of these regulations needs the approval of the Member States and the European Parliament. As of January 2010, the regulations for metadata, network services (discovery and view), and monitoring and reporting have already been approved. Those for data- and service-sharing policy, network services (transformation and download), and the first set of specifications for the harmonization of data have been approved by the representatives of the Member States and are now under the scrutiny of the European Parliament.

INSPIRE has some characteristics that make it particularly challenging. The most obvious is that it is an infrastructure built by 27 different countries using more than 23 languages. The requirements for multilingual services and interoperability among very different information systems and professional and cultural practices are, therefore, very demanding. This means, for example, that existing standards have to be tested in real distributed and multilingual settings. In the best scenario, all works well, but for a European-wide implementation, there is a need to translate the standards and related

| **Annex I** |
|---|
| Coordinate reference systems |
| Geographical grid systems |
| Geographical names |
| Administrative units |
| Addresses |
| Cadastral parcels |
| Transport networks |
| Hydrography |
| Protected sites |
| **Annex II** |
| Elevation |
| Land cover |
| Orthoimagery |
| Geology |
| **Annex III** |
| Statistical units |
| Buildings |
| Soil |
| Land use |
| Human health and safety |
| Utility and governmental services |
| Environmental monitoring facilities |
| Production and industrial facilities |
| Agricultural and aquaculture facilities |
| Population distribution and demography |
| Area management/restriction/regulation zones and reporting units |
| Natural risk zones |
| Atmospheric conditions |
| Meteorological geographical features |
| Oceanographic geographical features |
| Sea regions |
| Bio-geographical regions |
| Habitats and biotopes |
| Species distribution |
| Energy resources |
| Mineral resources |

*Table 1: Key data themes addressed by INSPIRE.*

guidelines into the relevant languages (International Organization for Standardization [ISO]; Open Geospatial Consortium, Inc. [OGC]; and other relevant standards are typically in English only). In other instances, testing has demonstrated that the standards are not mature enough, or leave too much room for different interpretations, and thus require further definition or individual bridges to make different systems interoperate. This can be seen with tests on distributed queries in catalogues all using the same specifications (OGC Catalog Service for the Web 2.0). The tests identified a number of shortcomings that required the development of an adaptor for each catalogue, which in a European-wide system with thousands of catalogues would obviously not scale.

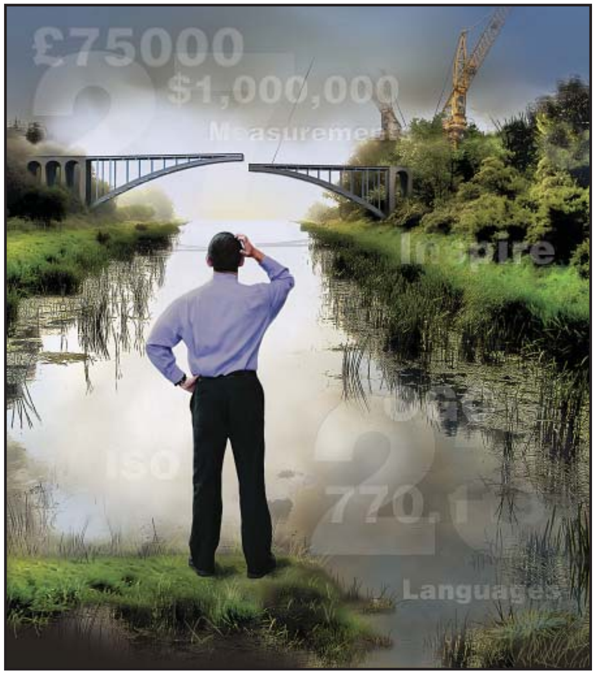
These shortcomings have been put forward to the OGC for consideration (for further details, see inspire.jrc.ec.europa.eu/reports/DistributedCatalogueServices_Report.pdf). In harder cases still, there are no standards available, and, therefore, they have to be created. This applies, for example, to "invoke" services that are needed for service chaining and to the specifications required for the interoperability of spatial datasets and services, which is a central feature of INSPIRE. To understand the context, it is worth reminding readers that each country in Europe has its own heritage and traditions, which include different ways and methods for collecting environmental and geographic data and different traditions on how to analyze and visualize the data, including different coordinate reference systems (sometimes more than one in each country), projections, and vertical reference systems. These different traditions mean that it is not enough for an SDI in Europe to help users find and access data. It is also necessary to understand the meaning of what we are accessing to make appropriate use of it.

This means, in turn, that we need to develop not only translation tools to help overcome the language barriers but also agree on reference frameworks, classification systems and ontologies, data models, and schemas for each of the data themes shown in table 1 against which the national data can be transformed or mapped. This is necessary because we cannot ask the Member States and their national and local organizations to reengineer all their databases. Thus, the approach adopted is to develop agreed-upon European models and systems of transformation (on the fly or batch) so that the level of interoperability necessary for key European applications can be achieved. The approach sounds simple, but putting it into practice is very complex, as it has already required three years of work to develop an agreed-upon methodology (the Generic Conceptual Model) and tools; mobilize hundreds of experts in different domains; and deliver and test the first round of specifications for the Annex I data themes, with Annexes II and III to follow in the coming years. A visit to the INSPIRE Web site (inspire.jrc.ec.europa.eu/index.cfm) in the data specifications sections demonstrates the huge amount of work involved.

## The Organizational Model

The organizational model put in place to develop INSPIRE is one of its more interesting features, drawing significant attention from outside Europe. In essence, it is a huge exercise in public participation, the like of which is most unusual in policy making, at least in Europe. From the outset, it was recognized that for INSPIRE to be successful and overcome the barriers to data access and use identified earlier, it was necessary for the legislators, implementers, and practitioners in the Member States to come together and agree on a shared understanding of the problem and possible solutions. Therefore, an expert group with official representatives from all the Member States was established at the beginning of the process in 2001, together with working groups of experts in the fields of environmental policy and geographic information to formulate options and forge consensus.

The INSPIRE proposal was subject to an extended impact assessment (inspire.jrc.ec.europa.eu/reports/fds_report.pdf and inspire.jrc.ec.europa.eu/reports/inspire_extended_impact_assessment.pdf) to identify potential costs and benefits before opening for public consultation. The revised proposal was then debated by the Council and European Parliament over a three-year period before final adoption in 2007. This process in itself is a good example in democracy, but the more interesting aspect is the way in which interested stakeholders are continuing to participate in all the ongoing activities required to develop the INSPIRE implementing rules (i.e., the follow-up legal acts and detailed technical guidance documents).




To organize this process, two mechanisms have been put in place: the first is to engage the organizations at European national and subnational levels that already have a formal legal mandate for the coordination, production, or use of geographic and environmental information (called Legally Mandated

Organizations, or LMOs). The second mechanism aims to facilitate the self-organization of stakeholders, including spatial data providers and users from both the public and private sectors, in Spatial Data Interest Communities (SDICs) by region, societal sector, and thematic issue. The central roles that SDICs play in the development of implementing rules include the following:

- Identify and describe user requirements (to be understood as acting in line with environmental policy needs, as opposed to "maximum" requirements beyond the scope of INSPIRE and beyond realistically available resources).
- Provide expertise to INSPIRE drafting teams.
- Participate in the review process of the draft implementing rules.
- Develop, operate, and evaluate the implementation pilots.
- Develop initiatives for guidance, awareness raising, and training in relation to the INSPIRE implementation.

LMOs have similar functions but also play a central role in reviewing and testing the draft implementing rules and in assessing their potential impacts in respect to both costs and benefits.

An open call was launched on March 11, 2005, for the registration of interest by SDICs and LMOs that were also asked to put forward experts and reference material to support the preparation of the implementing rules. The response was immediately very good, with more than 200 SDICs and LMOs registering within a month, putting forward some 180 experts (funded by them) from which we have set up drafting teams to help in developing the first batch of technical documents. At the present time, a second call for experts is open on the INSPIRE Web site to support the development of Annex II and III specifications, and an Internet forum (inspire-forum.jrc.ec.europa.eu) has also been set up for Member States to share experiences and tools to help implement INSPIRE. Table 2 shows the extent of the community directly involved in shaping the policy and the technical documents.

Three aspects are particularity important in understanding the work and the challenges of the drafting teams: first, each expert represents a community of interest and, therefore, has the responsibility to bring to the table the expertise, expectations, and concerns of this community; secondly, each drafting team has to reach out to all thematic communities that are addressed by INSPIRE. As a matter of comparison, it is worth recalling that the U.S. NSDI defined only seven framework themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information, most of which have a federal agency that is taking the lead in data collection and management. The implication for the drafting teams is that they have a much more difficult task in collecting and summarizing reference material, seeking common denominators and reference models, and developing recommendations that satisfy user requirements without imposing an undue burden on those organizations that have day-to-day responsibility for data collection and management across Europe. Seeking compromise between different requirements and perspectives is crucial to the work of each drafting team.

| The Inspire Community in 2009 |
|---|
| 361 Spatial Data Interest Communities (SDICs) |
| 198 Legally Mandated Organizations (LMOs) |
| 300 experts (drafting teams and working groups) |
| 238 experts for Annex II/III latest call |
| 3,087 user organizations registered on the INSPIRE Web site |

*Table 2: The INSPIRE Community in 2009.*

Last, but not least, it is important to note that the drafting teams have ownership of their work. They make the recommendations and submit them for review to all the registered SDICs and LMOs and the representatives of the Member States. It is only after they have taken on board all the comments received that the Commission takes ownership of the draft implementing rules and submits them for internal consultation. After revision and checking, the draft implementing rules go through the final round of the democratic process before becoming a new legal act. This involves qualified majority voting by the representatives of the Member States and the scrutiny of the European Parliament.

The complexity of this participatory approach is certainly innovative not only in relation to the developments of SDIs but also more generally to the formulation of public policy at the European level. The outcome produces both consensus-based policy and the development and maintenance of a network of stakeholders that make it possible to implement more effectively this distributed European SDI.

## The Challenges

Although a great deal of work has clearly taken place with the support of many stakeholders, there are still several organizational and technical challenges (and opportunities) that need to be addressed.

**Organizational:** The most immediate challenge is to maintain the momentum and the high level of commitment of all stakeholders and the experts contributing to the development of the implementing rules. This is not trivial and requires a notable amount of resources (time, money, expertise, commitment) to ensure that stakeholders feel ownership of the process, which then becomes a prerequisite for more effective implementation. Just to give an example of the scale of the task, the development of the data specifications for Annex I themes involved addressing more than 7,500 comments received from hundreds of stakeholders and organizing some 350 meetings (both physical and virtual) over a two-year period. If you consider that there were 8 themes in Annex I and another 26 to do, in addition to the revisions and maintenance of all guidance documents already created, then you have a sense of this facet of the organizational challenge. The INSPIRE forum is one way to address this challenge, but managing expectations, ensuring real participation, and delivering the benefits are key aspects we constantly need to focus on.

Another facet, which is even more important, is the organizational challenge in the Member States to implement INSPIRE. The INSPIRE Directive asks Member States to establish and maintain their SDIs, nominate an organization as a contact point with the Commission, and set up appropriate coordinating mechanisms, all of which have given rise to a flurry of activity across Europe. In many countries, SDIs already exist and work well at national and subnational levels. So the effort is more focused on agreeing on a division of responsibility than in setting up new structures. In other countries, INSPIRE offers an opportunity for the organizations that have been leading SDI developments for years to get their just recognition and acquire new status and legitimacy.

Of course, the difficult financial climate of this period makes it potentially more challenging to invest in new infrastructures and ways of working. Hence, the challenges in most countries are to leverage resources available from different sources (European, national, international) and/or ensure strong synergy between the investment required by INSPIRE and those committed in related projects, for example, in the framework of e-government. In this sense, the work needed is critical not only to align sources of funding but also to ensure that initiatives, standards, systems, and deployments are well coordinated and that they do not duplicate, or contradict, each other. Readers of this article who are familiar with large public-sector organizations will know how challenging this may prove to be.

Underpinning this organizational challenge are the key issues of awareness, education, and training. Although we have involved thousands of people in the development of INSPIRE, and most national-level organizations in the Member States are aware of this initiative, there is still much to do. Even in the organizations involved in INSPIRE, sometimes only a few people are actively participating, and the level of awareness of INSPIRE and its future impacts may be lost to other parts of the same organization.

Moreover, many public-sector administrations at the subnational level still have limited or no knowledge of INSPIRE. This is partly due to (1) insufficient dissemination efforts in the Member States; (2) local and regional authorities only becoming more directly involved when the data themes they are responsible for, which are mainly in Annexes II and III, are addressed by INSPIRE; and (3) the complexity of the technical documentation being produced at the present time, which very few people can understand or use. This brings us to the education and training issues. Even if we take a very simplified view of an SDI and assume that all it involves is creating metadata and setting up OGC-compliant services for discovery, view, and access, then where are the technicians versed in the relevant standards and technologies who will be able to implement these services across hundreds of datasets in the thousands of organizations across Europe? Who is training them? Where are the technical colleges and universities forming such competent technical staff? Where is the training material consistently being designed and translated across Europe so that everybody implements exactly the same specifications? And, where are the courses to train professional users (city planners, environmental engineers, social scientists, etc.) on the added value of the SDI to their work? The answer, of course, is that we still have to build up this capacity.

There have been notable efforts in respect to the professional users such as the Center for Spatially Integrated Social Science in the United States (www.csiss.org) and several EU-funded projects in Europe (e.g., www.vesta-gis.eu), but the demand far outstrips the supply, and often, the funding to support these projects is limited to a few years, typically three or four. An interesting effort to overcome this short-term funding problem is represented by the Vespucci Initiative for the Advancement of Geographic Information (GI) Science (www.vespucci.org), a not-for-profit, self-funded initiative bringing together leading GI scientists and practitioners in intensive weeklong courses to foster interaction and exchange of experience along the "training the trainers" formula. After eight years of operation, some 500 participants have lived the Vespucci experience, and thousands more will have benefited from the indirect effects of being trained by the Vespucci alumni.

**Technical:** The main challenge here is to develop and maintain an infrastructure that works and that delivers added value. As indicated earlier, the suite of international standards and specifications available is sometimes not mature enough to deliver or is subject to different interpretations, change, and inconsistencies. To give one small example, at the core of SDIs is metadata. The international standards for metadata for datasets and services are ISO 19115 and ISO 19119, respectively. The application schema for both is ISO 19139, but these schemas can be found at two different locations: the ISO repository for official standards and the Open Geospatial Consortium Schema Repository. Unfortunately, the schemas available at these two sites differ because of the different versions of Geography Markup Language (GML) they use.

This is now being addressed, but it is just one example of the many problems one has to face in practice. The devil is always in the details, and in the case of INSPIRE, we took the view that it was not feasible to include all the very detailed specifications down to rules for encoding into a legal act, as any change in standards, technologies, or good practice would then require lengthy procedures to amend the legislation. As a result, the INSPIRE implementing rules are short and only say what functionalities are required, leaving the detailed implementation to nonbinding guidelines documents. This has its drawbacks, as we cannot guarantee that everyone will use the guidelines and that interoperability will be achieved immediately. On the other hand, experience has shown that we are still making small adjustments to the guidelines for metadata two years after their approval. Had they been set in tablets of stone (i.e., legally binding), there is no way that we could be able to make any change fast enough.

So, in practice, we adopted a more pragmatic approach, setting up an Initial Operating Capability Task Force with representatives from the agencies in charge in every country to implement INSPIRE. With them we can discuss in detail how they are implementing their services, what seems to work, and what does not; make the necessary changes and adjustments; and disseminate good practice, as well as share tools (and reduce costs). INSPIRE is a process, not just an artifact!

A second challenge is to facilitate the transition from a spatial data infrastructure perspective, that is, the "extended GIS metaphor" used in the introduction, which only addresses relatively few technical experts, toward a spatial information infrastructure, a service providing information products and analyses that are of wider use to nonexperts. This requires turning many of the functionalities and analytic processes encoded in GIS software and usable by few trained geospatial professionals into geoprocessing services that can operate in established workflows over the datasets available on the Web and provide answers to questions posed by the many who are not experts.

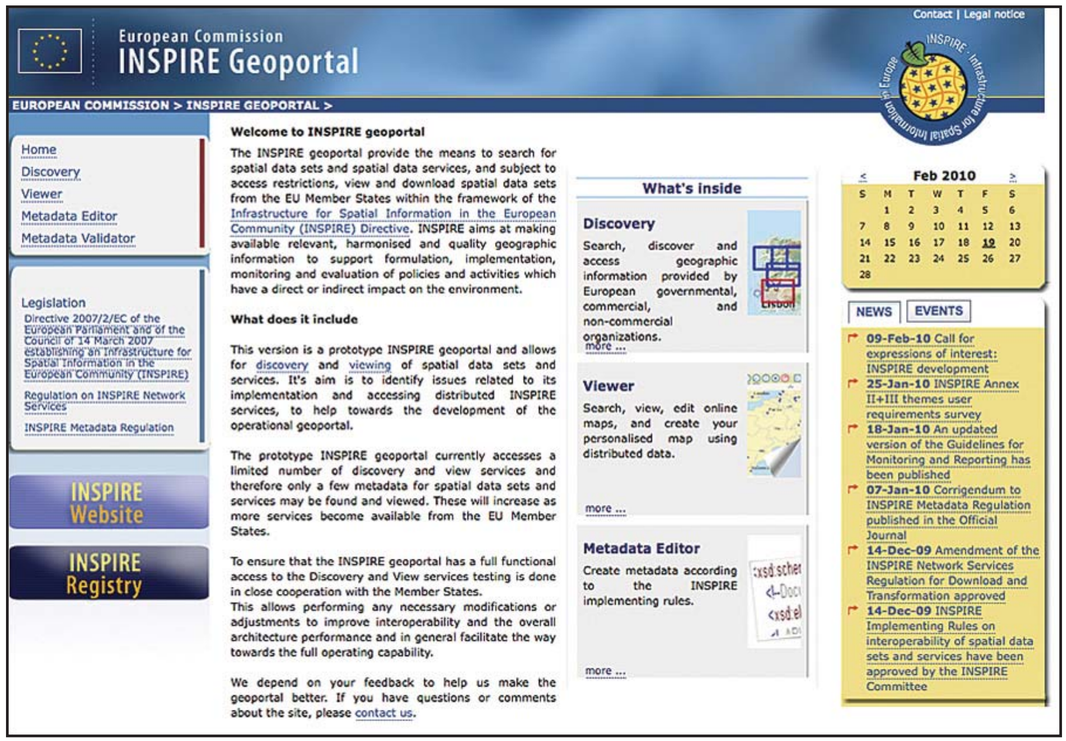
The research issues here are many and include eliciting and formalizing processes and models from experts; turning them into geoprocesses, which can be understood and used across disciplines (including explanation of the theoretical underpinning of models so that they can be used appropriately); and selecting the appropriate service to go with the appropriate data to contribute to addressing a question in ways that are methodologically robust. Some of these challenges were addressed, for example, by the ORCHESTRA project (www.eu-orchestra.org/overview.shtml), but in that instance, all the geoservices had to be chained manually, which would not scale up in a global setting with thousands of datasets and services available. So we need automatic or semiautomatic means of making the right choices and links.

To add spice to these challenges, there are also always new ideas and technologies to understand and harness. So as we were settling in to implement service-oriented architectures (SOA) for SDIs with the corollary of ISO metadata, OGC discovery services, etc. (i.e., following the paradigm of the library that separates the resources from their metadata), along came Linked Data (linkeddata.org) with Resource Description Framework (RDF) to provide semantically rich descriptions of resources and their linkages. Of course, Linked Data and SOA are not necessarily at odds. However, this is a good example of the way one needs to build the infrastructure for today with a view to where we should be going tomorrow.

## Toward the Next-Generation Digital Earth

To help sharpen our vision of the future, the Vespucci Initiative brought together in 2008 a number of environmental and geographic information scientists from academia, government, and the private sector to consider the changes that have taken place since the 1998 Digital Earth speech by U.S. Vice President Al Gore (www.isde5.org/al_gore_speech.htm). The meeting was an opportunity to consider the major technological developments that have made it possible to bring the experience of Digital Earth to hundreds of millions of people in their homes and desktops. It also reviewed the many public-sector-led initiatives aimed at organizing geographic information (SDIs and INSPIRE, the Global Earth Observation System of Systems initiative [earthobservations.org], the International Society for Digital Earth [www.digitalearth-isde.org], etc.) and the major private-sector developments aimed at organizing world information geographically. These have made it possible for citizens to contribute and share geographic information easily and interact with each other in what is labeled as Web 2.0.

Overall, the emerging view was that there is a need to bring together these seemingly parallel worlds: top-down official information and bottom-up citizen-provided information. On this basis, we articulated a revised vision of Digital Earth to help guide our effort. This vision recognizes the need to integrate scientific and public- and private-sector data to help us understand the complex interactions between natural, man-made, and social environments over time and across space—a framework to help us realize what has changed or is likely to happen, when, and why. To support this vision, we also identified key research topics on which to focus our energies, including improved methods for the spatiotemporal modeling of heterogeneous and dynamic data (citizen provided, sensors, official), the visualization of abstract concepts in space (e.g., risk, vulnerability, perceived quality of life), and ways to assess and model reliability and trust in information coming from many different sources (for more details, see ijsdir.jrc.ec.europa.eu/index.php/ijsdir/article/view/119/99).




*The INSPIRE geoportal (www.inspire-geoportal.eu).*

You could argue that with all the work we still have to do to develop and implement INSPIRE in Europe, we can ill afford to look for new organizational and technical challenges and research topics. Yet we should never lose sight of why we are building these infrastructures and investing significant public resources to do so. They are not ends in themselves but a means to improve our understanding and stewardship of the environment and develop our knowledge-based society. Without a clear view of where we want to go and what is needed to get there, we will not be able to guide the process effectively and address the grand challenges of today and tomorrow. The *Next-Generation Digital Earth* paper provides an initial contribution in shaping the longer-term view, and we welcome your feedback and contributions on inspire-forum.jrc .ec.europa.eu/pg/groups/ 98/next-generation-digital-earth.

## About the Author

Max Craglia works in the Spatial Data Infrastructures Unit of the Joint Research Centre of the European Commission. This unit is responsible for the technical coordination of INSPIRE, working closely with other Commission colleagues in the Directorate General for the Environment and EUROSTAT. Craglia edits the *International Journal of Spatial Data Infrastructures Research* (ijsdir.jrc.ec.europa.eu) and is one of the founders of the Vespucci Initiative for the Advancement of Geographic Information Science (www.vespucci.org).

(Reprinted from the Spring 2010 issue of *ArcNews* magazine)

# Mukund Rao Steers Data and GIS for Global Spatial Data Infrastructure

A geologist by education, Dr. Mukund Rao understands how studying the earth can uncover solutions to problems that affect people all over the world. His passion for understanding the earth and its activities led Rao to a rich career furthering earth observation, GIS, and spatial data infrastructure (SDI) applications at both the national and international levels.

To honor this exemplary work record for the past three decades, Rao has been bestowed two honors, the 2008 National Geospatial Award for Excellence from the Indian Society of Remote Sensing and the Exemplary Service Medal from the Global Spatial Data Infrastructure (GSDI) Association. The Indian Society of Remote Sensing recognized Rao's outstanding contributions in promoting geospatial science and technology and applications in India through longtime association and involvement in GIS technology, including his current position as president and chief operating officer of NIIT GIS Limited (ESRI India). The GSDI Association recognized Rao for his role in building and developing GSDI in its formative years and steering its activities as its first president from 2004 to 2006. Rao served as president at the GSDI-7/8 conferences in Bangalore, India/Cairo, Egypt, and has been involved in directing and furthering the technology and application of SDI throughout the world.

"To me, these awards are a humble reminder of the opportunity I've had to work with GIS right from the beginning," says Rao. He was introduced to GIS in 1984 while working at the Indian Space Research Organization (ISRO) to create the first prototype of the Natural Resources Information System (NRIS), a solution for handling images, making thematic maps, and supporting decision making in natural resources management. Rao conceptualized and performed an initial study for the Mineral Exploration Information System (MEIS), which was an integration of images with geophysical and geochemical data that allowed analysts to find mineral indicators. Rao discovered GIS through a course introducing the fundamental concepts of GIS in Mumbai, India, led by one of the early originators of GIS, Dr. Duane Marble, professor emeritus of geography at the Ohio State University.

*Mukund Rao is a GIS Hero.*

Later, in 1987, Rao was exposed to an excellent training suite in GIS at the Asian Institute of Technology (AIT).

In 1985, Rao was involved in the process of selecting the best-suited GIS package for the support of India's remote-sensing applications and the NRIS program (finally, ISRO selected PC ARC/INFO, then the later versions of ArcInfo). "The innovative methods of handling maps, building spatial models, and creating different spatial perspectives captivated me right away—I could easily perceive their importance and relevance due to my background in geology, where maps and visualization are the key," adds Rao. He went on to apply GIS to urban and regional planning and wasteland management in many cities in India. Ultimately, he became the lead in the NRIS program of ISRO and was instrumental in developing the comprehensive NRIS Standards for GIS in India and, more recently, the National Natural Resources Management System (NNRMS) Standards, the national standards for EO and GIS.

During the late 1990s, Rao realized that SDI was the path for both the NRIS and ISRO imaging programs, conceptualizing India's NSDI program and transforming it into an intergovernmental mechanism. Rao was the key person in authoring the *NSDI Strategy and Action Plan* and prepared the NSDI Metadata Standards. To demonstrate the first GIS portal for NNRMS, Rao developed a prototype that was officially launched and hosted on ISRO's Web site in early 2000. Soon after, he steered the concept of agency SDI portals through the National Urban Information, NNRMS, and a number of state-level portals of SDI, bringing about an integrated system for India's NSDI. This system is now becoming the foundation of NSDI in India. He is currently working on concepts for SDI Applications Portal services and enabling a cross-linking network of application visualization for SDI.

This activity launched Rao into the GSDI movement, and he was elected as the first president of the GSDI Association. During this time, GSDI was incorporated and its activities defined, including a coordinated approach furthering SDI throughout the world through cookbooks, Esri grant projects, conferences, and committee activities.

In 2005, Rao took over as CEO of Navayuga Spatial Technologies, an Indian startup company located in Bangalore, and headed up many successful projects, including the establishment of an ArcGIS software-based enterprise solution for the Ras-Al Khaimah emirate in the United Arab Emirates (UAE) and the largest enterprise solution project in India, the creation of an SDI in Delhi.

Since joining ESRI India in 2008, Rao has been involved in furthering GIS throughout India by promoting efficient and successful business models. With a deep understanding of earth observation and GIS, Esri India now operates and helps many successful GIS projects in India and other parts of the world, focusing on urban, power, utilities, disaster, and imagery sectors.

Rao is quick to point out that his associations with other leaders in the field have helped him achieve his successes in spearheading the movement of GIS and remote sensing to assist in solving the challenges faced in the world. Jack Dangermond, president of Esri, and Dr. Krishnaswamy Kasturirangan, the former chairman of ISRO and chairman of the Planning Commission of India, are two such leaders. Rao also credits a large number of professionals that he has worked with in India and abroad for his GIS accomplishments, learning from their capabilities and expertise in undertaking GIS activities in a better and meaningful way.

Rao is a strong believer that GIS representation will be a key factor in most human activities and a benefit to society and humanity, providing the key technology necessary for information processing and visualization. "While, on one hand," says Rao, "GIS will become easier and simpler to use—thus making it usable by the common man—it will also become integrative and overarching to bring together various technologies of surveying, imaging, and mapping for GIS content; databases and warehousing for GIS storage; and seamless data fusion and merging for GIS applications. Finally, it will provide a tremendous way of visualizing information in a spatial domain. No longer are maps the only output from a GIS."

(Reprinted from the Winter 2009/2010 issue of *ArcNews* magazine)

# Remote Communities Prevail with GIS

## *Small Island SDI Is a Huge Success*

Highlights

- GIS managers feel a sense of community even on small islands in the middle of the ocean.
- The islands use ArcGIS as the backbone for spatial data sharing.
- Benefits are derived from land being carefully mapped and documented with GIS.

GIS for spatial data infrastructure (SDI) is used throughout the world to instill cooperation and collaboration in sharing spatial data to better address social, economic, and environmental issues. It seems logical that large countries like the United States have invested in SDI, such as the Geospatial One-Stop, and national unions, such as the European Union, have come together to share data and resources via the Infrastructure for Spatial Information in Europe (INSPIRE). Does SDI make sense for smaller countries and communities? Arguably, even smaller nations benefit from land being carefully mapped, public works and utilities documented, environments and biodiversity protected, and resources assessed and strategic planning completed.

Thanks to special funding through the joint United Kingdom Foreign Office/ Department for International Development Environment Programme, a group of UK overseas territories and the member states of the Organization of Eastern Caribbean States are able to rely on GIS for SDI, using the solution for data quality and control, information sharing, and delivering finished products for use between governmental agencies and private organizations. Calling themselves "tiny SDI," these small islands use ArcGIS as the backbone for spatial data sharing.

*A few thousand of the half million wide-awake (sooty) terns on Ascension Island (photo credit: Alan Mills).*

Most islands were using Esri GIS software products in some form or fashion before SDI was implemented. As Alan Mills, principal with Alan Mills Consulting, Ltd., and one of the thinkers behind using SDI to help manage smaller islands, explains it, "We realized there was synergy in sharing the same add-on applications developed with GIS across the islands. Along with the backup support from other islands doing the same functions, the GIS managers on these remote places would feel a sense of community and have a place to go when they needed help. This is important when you live on a small island in the middle of the ocean three days' boat ride from the nearest airport, and you have to be the expert in GPS, databases, cartography, digitizing, and changing the ink in the plotter. Many of these projects produce baby steps in making SDI, but these smaller islands should not be excluded from making best use of GIS for their own special purposes."

## Ascension Island Discovers Data Sharing

One island that has many unique needs housed in a small space is UK overseas territory Ascension Island, situated in the sea halfway between Africa and Brazil. Only 34 square miles in area (approximately 88 square kilometers), the island is inhabited by about 1,000 people. Because the island is a relatively recent volcanic emergence close to the Mid-Atlantic Ridge, there is little natural vegetation except for a few species of ferns and spurge, a plant that exudes a bitter milky juice. The island became a refuge for a wide variety of marine species and is the second largest Atlantic nesting site for green turtles.

Humans discovered the island in the 1500s, and since that time, the island's ecology has changed significantly: invasive plant species have run rampant over parts of the island and rats and cats have decimated the bird populations. Bird and turtle populations have oceanwide impact on biodiversity, and the Conservation Department established by the small Ascension Island government is mandated to protect and enhance the crucial nesting sites, as well as conserve the local plants, crabs, and invertebrates.

Since 2005, GIS has been used to synthesize disparate databases and datasets and create new maps and images for environmental management. GIS also assists with other applications, including the Environmental Health Department's rat control mapping, and documenting of an eclectic set of historical sites, such as the guns of the sunken HMS *Hood,* Dampier's Drip (the original freshwater source for the island), and concrete water catchments in the mountainside that collect scarce cloud water for the island's predesalination plant.

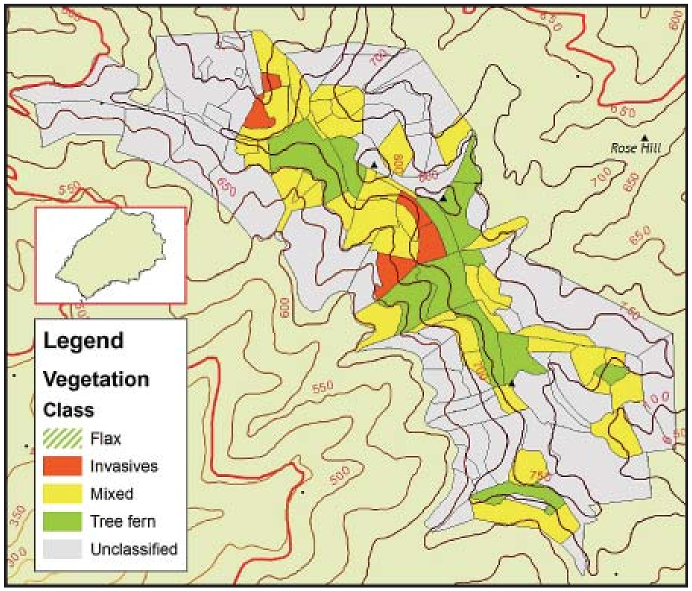
Using ArcView, a component of ArcGIS Desktop, the system works well. Says Dr. Edsel Daniel, professor, Vanderbilt University in Nashville, Tennessee, a codeveloper of the SDIs for Ascension and *St. Helena,* and a colleague of Mills, "The software is easy enough to be handled by nonexperts. We are able to use a flexible framework that accepts new monitoring data and can integrate datasets from a wide variety of sources and types."

ArcView integrates all the data necessary for the government to make informed planning decisions to balance environmental, amenity, and infrastructural priorities. Clear protocols and procedures have been determined to pass data from the field to the end user.

"The key to this system to function in such a small area so economically with great benefit is the fact that data gathered for one purpose can be shared in many applications," asserts Mills.

## St. Helena Finds Cooperation Is the Key

St. Helena, about 750 miles (1,207 kilometers) southeast of Ascension, cannot be reached by air. Instead, a visitor must take the RMS St. Helena, which plows between Cape Town, South Africa; St. Helena; and Ascension each month. Approximately 3,500 hardy settlers live on the island, many above the precipitous cliffs or in a narrow canyon where the well-preserved Georgian capital of Jamestown nestles, near landscapes of rocky desert, rolling pastures, and eucalyptus and pine plantations. Near the coast, humpback whale mothers and calves shelter themselves, and thousands of seabirds cling to cliff edges and stacks.



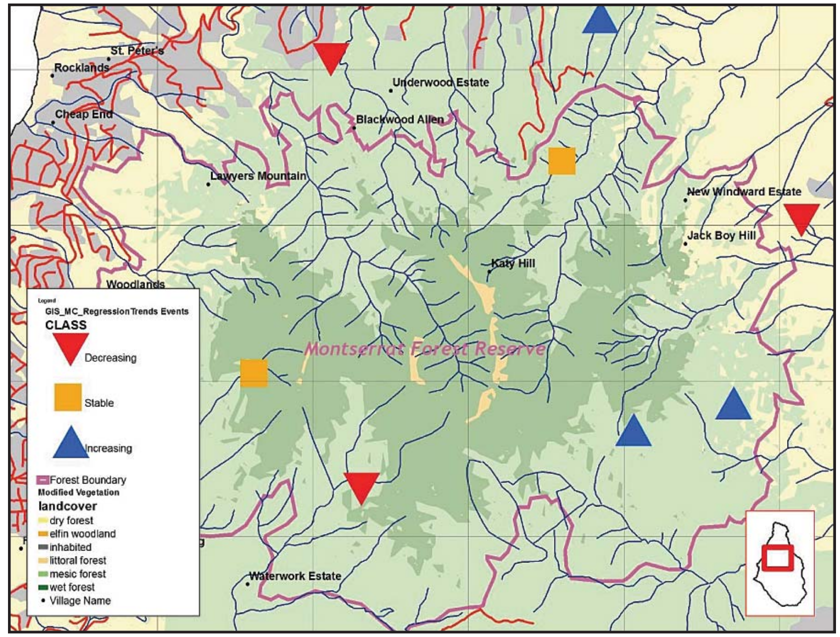

*This map shows endemic tree ferns, trees, and threatening weeds on St. Helen's Diana's Peak (as of 2007).*

At first, GIS was used to determine the best locations to place freshwater boreholes. In 2004, other projects began, the largest being building the island's cadastre. The St. Helena Agriculture and Natural Resources Department (ANRD), along with the St. Helena National Trust, implemented ArcView and a Microsoft Access database to monitor clearance of invasive flax and other plants and manage the growth of endemic cabbage trees and tree ferns. Len Coleman, GIS manager, St. Helena, says, "The emergence of a map showing the recolonization of endemics over a 10-year period gave other departments the idea to link their monitoring data with the mapping being accomplished."

A single system was then designed to minimize duplication of effort and share the burden of data collection and management. The St. Helena Legal, Lands, and Planning Department was keen on expanding its new cadastral GIS and database, and working with ANRD meant environmental concerns were known by the planning unit for both strategic plans and the development control process. Sharing resources also makes it easier for training sessions to be organized and held for occasional users of GIS. Data is not duplicated, and there is better quality control and attribution when it is used for multiple applications. Visiting scientists and consultants can search the data catalog and have a recognizable way of contributing information back to the system in a structured manner once their project is completed.

## GIS Keeps People and Mountain Chickens Safe on Montserrat

In the eastern Caribbean Sea, Montserrat is another UK overseas territory, approximately 12 miles (20 kilometers) west of Antigua. After a volcanic eruption in 1997, the population dwindled from 11,000 to 3,500 and is now settled in only one-third of the island. These few people on the island are in need of GIS to assist them in mapping safe zones and planning for permanent homes and services away from the dangerous area around the volcano. GIS is also used to map endangered species in the Center Hills area, including the curiously named mountain chicken, a frog that is a local delicacy and has been unfortunately decimated by a fungal disease. Work by the Department of Environment in Montserrat—supported by the likes of the Durrell Wildlife Conservation Trust; the UK Royal Society for the Protection of Birds; and the Royal Botanical Gardens, Kew—is helping protect endangered species like the mountain chicken.




*A map defining trends of the mountain chicken habitat of Montserrat.*

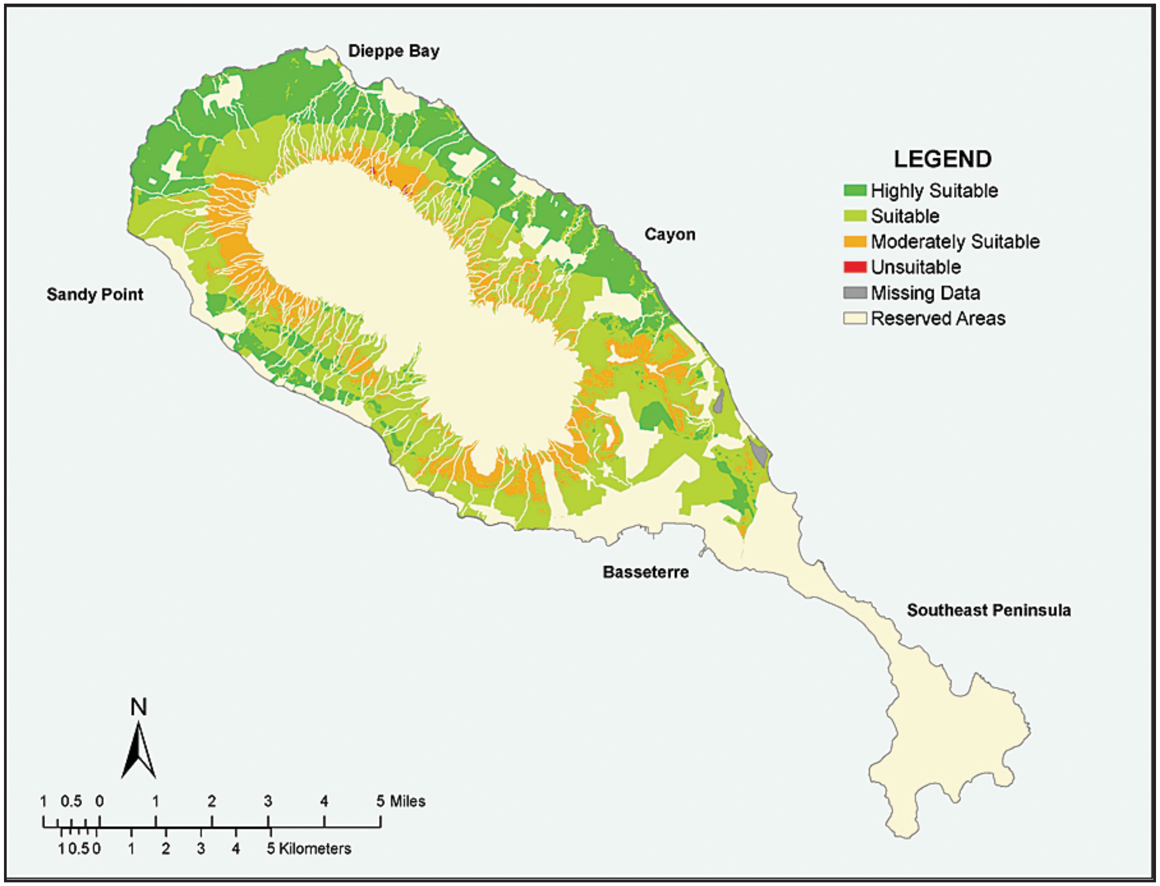
Led by GIS manager Lavern Rogers-Ryan, who works in the Montserrat Physical Planning Department, the GIS team uses ArcGIS to cover the requests of clients on the island, including updating the land cadastre and mapping for natural disasters and environmental protection. Comments Rogers-Ryan, "Assisting the Department of Environment in mapping its data opened our eyes to the spatial comparisons across the island."

Mills assisted in developing a database and training field staff in how to make simple maps. Rogers-Ryan emphasizes, "This assistance helped me better structure my data to provide wider services to several government departments without being overwhelmed by the work."

## GIS Used to Evaluate Land Resources for St. Kitts in a Postsugar Era

St. Kitts (also called St. Christopher) is part of an independent, twin-island federal state with the island of Nevis. Both islands have a total population of 39,000 and achieved their independence in 1983 when the British made them the smallest independent state in the Western Hemisphere. St. Kitts has a land area of 65 square miles (168 square kilometers) with extremely fertile soils used primarily for sugar production for the past 350 years.

Fluctuating commodity prices and reduced European Union trade preferences have made the island's reliance on single-crop agriculture an economic vulnerability. To address such vulnerabilities, in 2005 the government of St. Kitts and Nevis (GoSKN) made the decision to close the sugar industry and vigorously pursue its economic diversification by placing emphasis on more viable alternatives, such as tourism and nonsugar agriculture, including field crops and livestock. One of the major challenges of this effort is adopting careful planning to ensure that the island's land resources previously utilized by the sugar cane crops are optimized for the long-term economic, social, and environmental sustainability of the country.




*St. Kitts' land suitability map for vegetables.*

After the closing of the sugar industry, the GoSKN Physical Planning Department (PPD) and Department of Agriculture spearheaded the planning for the agricultural transition. A land resource analysis study was conducted using ArcGIS (ArcView) to identify the most suitable lands for six nonsugar agricultural activities: vegetable crops (e.g., tomatoes, peppers), pineapples, fruit tree crops (e.g., sugar apples, guava), field crops (e.g., cassava, sweet potato), livestock production, and pasture/grass (e.g., guinea grass for feeding livestock). "While specific areas have been quantified based on suitability," says Daniel (former PPD staff member and lead researcher on the study), "an added benefit of this study was the ability to identify, compare, and quantify areas for uses beyond agriculture. We were able to evaluate future land use, such as housing for tourism, industrial, and residential, along with suitable lands for nonsugar agricultural activities. Using GIS, we were able to see the bigger picture of how to develop areas for the benefit of the community."

## Mapping Resources on Rodrigues Island to Sustain Human Activity

Rodrigues is a partly autonomous island found approximately 400 miles (650 kilometers) east of its sister island, Mauritius. Third largest of the Mascarene Islands, Rodrigues has 40,000 people who live off reef and subsistence farming and has few support services and only a fledgling tourism industry.

Shoals Rodrigues, a nongovernmental organization working closely with the island's government, the Regional Assembly, conducts marine research, education, and training about the extensive reef area, which extends over twice the size of the land itself. One major activity is assessing the extent and health of the marine resources, including the corals, sea grasses, and mangroves. With the support of the Universities of Newcastle and Bangor in the United Kingdom, Shoals Rodrigues created a map of the basic reef structure using supervised classification of Landsat Enhanced Thematic Mapper data, with an eye to using QuickBird satellite imagery and ArcView in the near future for the more detailed map of the resources, as well as in educational work and governmental planning.

(Reprinted from the Fall 2009 issue of *ArcNews* magazine)

# Governance of the NSDI

By Will Craig, President of the National States Geographic Information Council

The concept of the National Spatial Data Infrastructure (NSDI) has been around since the early 1990s, and the name has been in existence since 1994, when President Bill Clinton used it to label his executive order creating it. The name sounded strange when I first heard it; why *infrastructure?* Then I realized that *data is infrastructure.* Everybody else got it too. It was the first time the United States began to see data as infrastructure—equivalent to concrete roadways and metal pipes. This was the new information age, and data was the basis for economic growth and environmental integrity.

It was a wonderful concept—liberating and energizing—but we have gotten much less than I was hoping for over the past 15 years. There are only a few success stories. As I see the problem, we simply have not organized ourselves very effectively. This article describes the current geospatial governance structure in the United States, discusses current problems, looks at state models for success, and makes recommendations for doing things differently at the national level.

Through a directive from the Office of Management and Budget (OMB), we have put significant effort into identifying key data elements in that infrastructure and assigning responsibilities to develop and maintain that data. The Federal Geographic Data Committee (FGDC) is charged with coordinating those efforts but does not have the power to make or enforce rules. Federal agencies continue to create "stovepipes of excellence" and cooperate only when desirable to themselves, very rarely because of outside pressure. Equally important, the NSDI has a federal focus and often does not meet the needs of state or local government—let alone the private sector or public.

State governments have done a better job of coordinating their state spatial data infrastructures. Ironically, they have gotten funding from FGDC to develop the strategic and business plans necessary to make the transition. Many states have geographic information officers (GIOs) to coordinate state-level activities and advisory councils composed of other stakeholders to help coordinate the activities of municipal, county, and tribal governments. A similar approach should be used at the federal and national level to create the governance structure that will allow us to finally reach the full potential of the NSDI.

Cracks in the system are becoming apparent to Congress. In June 2009, the Congressional Research Service published a report called *Geospatial Information and Geographic Information Systems (GIS): Current Issues and Future Challenges.* The report tries to address the questions of "how effectively [is] the FGDC . . . fulfilling its mission" and "how well is the federal government coordinating with the state and local entities" (see www.fas.org/sgp/crs/misc/R40625.pdf).

On July 23, 2009, the Energy and Mineral Resources Subcommittee of the House Natural Resources Committee held an oversight hearing on federal geospatial data management. Rep. John Sarbanes of Maryland quoted a U.S. General Accounting Office (GAO) report from his briefing material saying that only 4 of the 17 [sic] FGDC member agencies were in compliance. A video of that hearing and written testimony of witnesses is online at resourcescommittee.house.gov/ index.php?option=com_jcalpro&Itemid=27&extmode=view&extid=278. Most of the discussion in the hearing was about eliminating redundant data collection. Not much was about filling gaps.

## OMB, FGDC, and NSDI

The current federal geographic governance structure has a long history. In 1953, the federal executive OMB issued Circular A-16. Originally aimed at federal surveying and mapping activities, that circular has been revised several times and is now titled *Coordination of Geographic Information and Related Spatial Data Activities.* Circular A-16 is the basis for all federal geospatial data coordination efforts. OMB is a cabinet-level office, monitoring the performance of the various federal agencies that report to the president, guiding them when they stray, and making recommendations for future presidential budgets. This is a powerful office, but it has tended to delegate geospatial data coordination to FGDC.

FGDC was created in the 1990 revision to OMB Circular A-16. This is when the circular began looking at spatial data use and coordination across federal agencies. The committee consists of leaders from 30 federal agencies—up from 18 listed in the 2002 revision of Circular A-16. It is chaired by the secretary of the interior. The strength of the committee is determined by the strength of personalities running it, and that strength has varied over the years. Not all member agencies are fully committed, as indicated at the oversight hearing.

When the NSDI was created in 1994 by President Clinton's Executive Order 12906, its purpose was to "support public and private applications of geospatial data in such areas as transportation, community development, agriculture, emergency response, environmental management, and information technology." Responsibility for implementation was given to FGDC. With minor modifications to provide a special role for the new Department of Homeland Security, President George W. Bush continued the NSDI in his Executive Order 13286 in 2003.

There were weaknesses in all this. One of the things that went wrong fairly early was a fixation on *framework data.* These were the seven data layers that were seen as first steps toward fulfilling the vision of the NSDI: geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units. Circular A-16 describes these as the seven "themes of geospatial data that are used by most GIS applications." In fact, I most frequently use land-use and soil data for my environmental work and socioeconomic data for my urban planning work. But, these seven were seen both as easy first steps and as a solid frame to which other data could be referenced. To be sure, Circular A-16 lists some 34 data categories and assigns each to a federal agency, but few agencies are working on their assignments. Land use is not in the list of data categories—along with many other elements that we all find useful in our daily work.

It turned out that framework data was not so easy to complete or coordinate. The National Academy of Sciences points out that the Federal Emergency Management Agency (FEMA) needs land surface elevation data that is about 10 times more accurate than data currently available (2007) for most of the nation. The transportation layer is maintained in various forms by agencies including the U.S. Census Bureau and Department of Transportation, the latter having several different versions. The cadastral layer effort soon abandoned securing data on all private landownership and even smaller federal land holdings, leaving only large federal holdings, like Yellowstone National Park, and Public Land Survey corners.

One of the best success stories is GPS, something that was not seen as part of the NSDI. This technology was developed by a federal agency (the U.S. military), but kept relatively secret with only degraded access to it until 2000 when President Clinton opened the door for public access. Today, GPS is a multibillion-dollar industry with devices on the dashboards of cars, in cell phones, and even on dog collars. This happened within a single agency and outside our national data governance structure.

We knew early on that data could not be developed without a partnership between the federal government on the one hand and state, local, and tribal governments on the other. Those relationships were required in Clinton's NSDI executive order. They were underscored in a series of reports from the National Academy of Sciences. The first of these was *Toward a Coordinated Spatial Data Infrastructure for the Nation,* which predated Clinton's executive order and set the stage for it. Perhaps the most relevant today is the 2003 report, *Weaving a National Map: Review of the U.S. Geological Survey Concept of* The National Map, that envisioned a national quilt of high-resolution local data that could be rewoven into a national blanket of uniform quality.

## Data for the Nation

The National States Geographic Information Council (NSGIC) and others are starting to use the phrase *for the nation.* Imagery for the Nation (IFTN), Transportation for the Nation (TFTN), and Elevation for the Nation are examples of this new approach in labeling. To NSGIC, this term means something quite specific: data is available nationwide, it has sufficient spatial and topical resolution to meet the needs of all levels of government, and resources are available to keep the data current. The processes for conceiving, developing, and maintaining such data are described with 20 discrete criteria on the NSGIC Web site. Only a few data themes exist that meet these criteria.

There are four ways to produce data that meets the needs of all levels of government. The traditional way is for federal programs to deliver data at sufficiently fine resolution to meet everyone's needs. A good example of such a program is the Soil Survey Geographic Database (SSURGO) county soils maps provided by the Natural Resources Conservation Service; these maps provide sufficient detail for state and local applications, though not for individual farmers who want to manage their fields intensively. Also, the Census Bureau provides population and housing data at the block level and above—again, sufficient for all but the most detailed local needs. The National Wetland Inventory and the National Hydrography Dataset also fall into this category. Not many other examples exist. I call these "happy accidents." They almost always involve a federal partnership with state or local government, but those partnerships are matters of convenience and not the result of our governance structure.

A second way to meet the needs of all levels of government is through federal programs that allow state and local governments to participate through buy-up options. The IFTN program, proposed by NSGIC, starts with the U.S. Department of Agriculture's (USDA) 1-meter National Agricultural Imagery Program and allows locals to add sensors (e.g., four-band) and expanded coverage into nonagricultural areas. IFTN also provides for the business needs of local government with a higher-resolution 1-foot program that would be administered by the United States Geological Survey (USGS). This component also has buy-up options that include 6-inch resolution, true orthophotographs; increased horizontal accuracies; and other features important to local government. Ideally, states would coordinate the many local requirements and funding, making it easier for USDA, USGS, and their contractors to meet local needs.

A third way to meet the needs of all levels of government is for local government to collect data that meets its needs, with state and federal governments rolling this data up to summary levels sufficient for their more general needs. This is actually fairly rare, but I have a good example from McLeod County in central Minnesota. The county wanted 1-foot contour data and worked with several local cities and a watershed district to contract for services. USGS needed only 10-foot resolution for its National Elevation Database, but contributed financially so it could access the finer data, process it, and publish a 10-foot summary of the original county data. The Minnesota Department of Transportation also contributed to the effort. This partnership was recognized in 2008 with a commendation from the governor of the state of Minnesota.

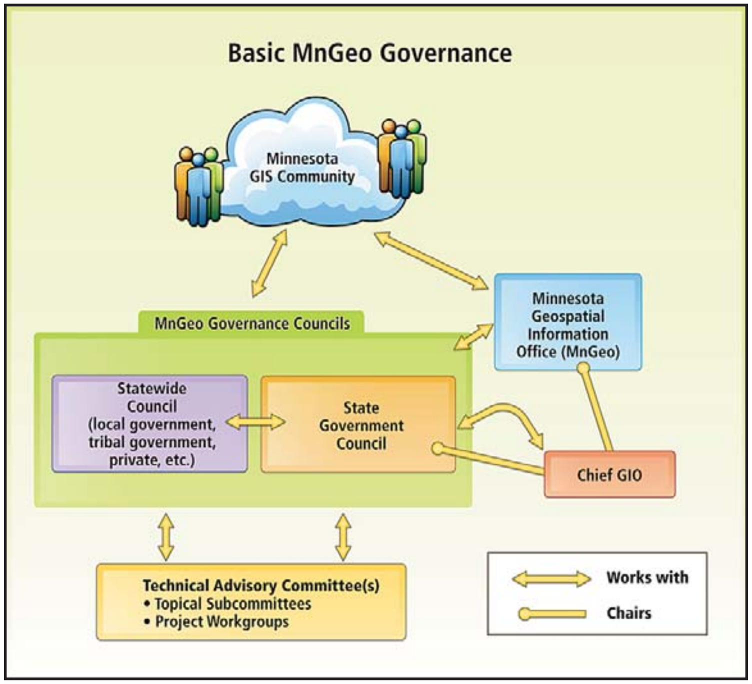
A fourth approach is for the private sector to get involved and create something that has value to the nation—enough value to support the enterprise. A number of popular Web providers of maps, travel directions, and aerial photos are doing a great job of delivering this kind of information to the public; much of the data comes from government sources, but it is delivered in useful packages by private firms. Ideally, we would base other work on public/private partnerships, so government has a say in the nature and availability of the final product. We lack good models on how this should work, but the potential is there.

## Parcels and Addresses

Parcels and addresses are especially useful pieces of the NSDI from my perspective. They present a conundrum for federal partnerships. Many federal agencies need such data for their day-to-day operations or in emergencies. This data is typically created and maintained by local government, but there is no systematic way for this local data to flow up to state or federal agencies as described in the third option above for delivering data for the nation. There is no system for collecting and organizing local data, so federal agencies collect their own data. Taxpayers foot the bill for multiple versions of the same data. No governing body in Washington has responsibility for resolving the conundrum—addressing the fragmented landscape.

Data on addresses is the most vexing because it is the closest to being ready for widespread sharing. The Census Bureau and the U.S. Postal Service have nationwide databases but share only with each other. A 1982 Supreme Court decision supports the Census Bureau decision to not share its Master Address File with local government. That decision was based on the court's understanding of congressional intent in writing Title 13 of the U.S. Code forbidding access to internal Census Bureau records, not on any intrinsic right of privacy. The past 27 years have brought significant developments in technology and business databases, making moot decisions about unknown addresses.

Most recently, the Census Bureau has spent millions of dollars hiring out GPS work to add an x,y coordinate to every front door in America. For some reason, this information is also held as nonpublic. I could easily see a system where I provide my address to the Census Bureau and it returns my x,y coordinate. Local governments and 911 authorities would love to have this information for their business needs but do not have the funds to collect this data themselves and cannot get it from the Census Bureau. I am not talking about internal and possibly illegal housing units, just about the front door that anyone could see when walking by. I am not talking about unknown places in the woods, only those buildings for which the local authority already has addresses. The x,y coordinates remain an internal, nonpublic resource at the Census Bureau, paid for with public funds, but not available to the public or any other government agency. Does this make sense?




Parcels are in a similar situation, but different because no federal agency has responsibility for maintaining a national parcel dataset. Nearly every domestic agency, save USGS, has the need for parcel data. USDA needs parcel data to manage its crop insurance programs. Our national parks and forests need information on parcels to communicate with neighboring landowners. FEMA needs parcel data for rescue and recovery operations; it wasted millions of dollars following Hurricane Katrina in aid to people who did not own property in the damaged area. The Census Bureau could use parcels on the outer edge of cities to update their governmental unit boundaries. The U.S. Department of Housing and Urban Development (HUD) could use parcel data to monitor urban decay or renaissance. Some would argue that access to good parcel data would have allowed us to foresee the recent mortgage crisis and intervene before things went so horribly wrong.

A 2007 report by the National Academy of Sciences looked at parcel data issues: *National Land Parcel Data: A Vision for the Future.* I was on the committee that drafted that report. We envisioned a Web mapping service that would allow people to see parcel maps, along with a limited set of attributes, for any place in the country without regard to county or state borders. States would play an intermediary role, adding their own landownership data and managing records for those local governments without sufficient internal capacity. This is technically and economically feasible. Yet the United States cannot do it because we lack the will and a governance structure to develop and manage such a system. The first recommendation of our study was to create a panel to identify a national coordinator to begin working on the governance issue. The Bureau of Land Management (BLM) has responsibility for the cadastre under OMB Circular A-16, so the panel would start by determining whether BLM has enough authority and capacity to do the job. Two years after our report was published, there is still no panel looking at this issue.

## States Are Organized

States around the country coordinate GIS activities better than the federal government. They typically have some kind of statewide council. The most effective councils coordinate activities at the state level with a strong hand but work gently with local governments. They include representatives from all stakeholder groups, including federal, state, county, municipal, and tribal governments; private-sector GIS users and providers; the academic sector; nonprofit organizations; utilities; and the general public. They have clear vision, supported by a strategic plan and a business plan.

The Fifty States Initiative was designed by NSGIC and FGDC to help states become effective coordinators. This initiative is intended to connect with the data resources of the 50 states and, through them, to the 3,141 counties, over 18,000 municipalities, and more than 370 tribal governments. To this end, FGDC has funded 46 states in developing strategic and/or business plans to support the NSDI.

NSGIC has developed a scorecard so each state can know how it stands on relevant criteria. The scorecard has nine criteria starting with a full-time coordinator and sustainable funding. More powerful criteria include a clearly defined authority for state-level coordination, the ability to coordinate with local government and other stakeholders, and a formal relationship with the state chief information officer (CIO).

My own state recently created the Minnesota Geographic Information Office (MnGeo). The state had been struggling with fragmented operations, and its NSGIC scorecard showed it. With a grant from FGDC, it hired a private firm to help bring together stakeholders and develop a governance model that would work *(see diagram above).* The plan called for the new MnGeo with two advisory bodies: one for *state government* coordination and one for *statewide* coordination. The state government advisory council is composed entirely of state agency GIS representatives. The statewide advisory council is composed of representatives of local government, the private sector, tribal government, nonprofit organizations, and academia. The GIO participates on both committees—as the chair of the state government council and as a nonvoting member of the statewide council.

*Illustration by Suzanne Davis, Esri*

## The National Solution

The simple solution is to "get organized," along the lines of what the states are doing. There are no technical problems in developing the NSDI, only organizational ones. Increased governance is necessary to make things work better. I see four parts to this new model: (1) creation of a new federal Geographic Information Office, (2) a radical empowerment of FGDC to coordinate federal GIS activities, (3) the creation of a new body representing nonfederal stakeholders, and (4) development of a congressional oversight committee to watch and guide overall activities.

At the federal level, we need a structure that supports and demands coordination of geospatial data development across federal agencies. This should start with the creation of a new position—a federal GIO. The office should be part of the Office of Management and Budget. OMB develops and executes a government-wide management agenda and assists the president in preparing his budget. It already houses the new federal CIO. This is the ideal place to set federal mandates for agency operations.

One of the first tasks of the new GIO should be to develop an economic argument for the NSDI. NSGIC has estimated the price of the NSDI at nearly $9 billion, with an annualized cost of about $2.5 billion. Is it worth it? If so, where are the highest payoffs? The effort should begin by defining a rigorous methodology that delivers results understandable to both economists and the educated public, including agency heads and members of Congress. The study should cover all levels of government, the private sector, and the public. NSGIC has suggested that the economic study should be delivered within 18 months after the GIO takes office. If the study shows positive benefits, support for the NSDI will logically follow.

FGDC should continue to coordinate activities at the federal level, but with more muscle behind its efforts. Duplicative activities should be identified and corrected. Agencies should be held accountable for fulfilling data assignments. Gaps should be identified, prioritized on economic return, and assigned to agencies. To operate effectively, FGDC probably needs to be moved from its current home in the Department of the Interior to OMB, since that organization has the mandate to review the performance of federal agencies and make budget recommendations affecting them.

Over time, I have written two contradictory articles about what it takes to make a difference in the world of sharing data. In 1995, I wrote about institutional inertia and the need for a body outside the organization, usually the chief executive or legislative body, to set the rules for organizational mandates and individual rewards. Later, in 2005, I recanted, as I recognized the value of "white knights" who are motivated to do what is right regardless of the institutional rules. I think I was right the first time—at least for something as large and complex as the NSDI. Certainly, large federal agencies need that outside oversight.

A National Spatial Data Council (NSDC) is needed to coordinate nonfederal activities. This idea has been around for years. I took this name from a 1998 report of the National Academy of Public Administration, *Geographic Information for the 21st Century.* The NSDC, or whatever we decide to call it, should be composed of stakeholder representatives from state, local, and tribal governments; the private sector; academia; and others. The representation should look much like that of the current National Geospatial Advisory Committee to FGDC, but would have power, grant-making ability, and access to the GIO. The federal government should be represented by FGDC as a nonvoting member.

A new congressional oversight committee could do three things: set the expectations for federal agencies and the new NSDC; monitor performance, asking hard questions; and become the political champion to support the development and maintenance of the NSDI.

As a nation, we have gone nearly two decades with limited progress on the NSDI. Most of that progress has been made through the goodwill and volunteer efforts of altruistic people and organizations. We are in the information age, but we're still building stovepipes. It's time to put some muscle and money behind the NSDI vision.

## About the Author

Will Craig is associate director of the Center for Urban & Regional Affairs at the University of Minnesota. He chaired URISA's Research Agenda Group in the mid-1980s, proposing an agenda that had a strong focus on institutional research. He is the president of NSGIC and has been inducted into URISA's GIS Hall of Fame.

(Reprinted from the Fall 2009 issue of *ArcNews* magazine)

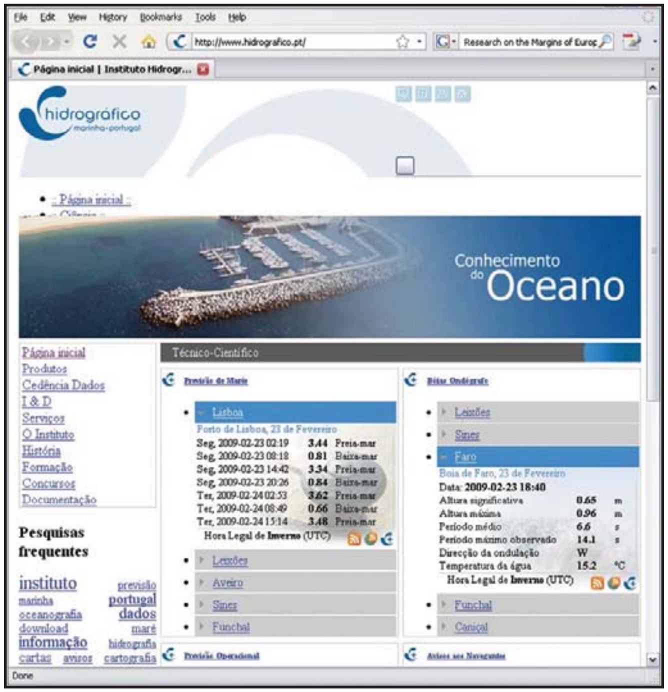
# A Geospatial Foundation

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

By Miguel Bessa Pacheco, Instituto Hidrografico, Portuguese Navy

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

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




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

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

## IDAMAR SDI Architecture

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

### Communications networks

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

### Database and data models

Several databases were developed using either DBMS- or file-based systems. The choice of system was based on the type of data stored and how that data could be most efficiently used. Data models for DBMS storage were internally developed for information processes except for chemical lab analysis data. A commercial laboratory information management solution, Thermo Nautilus LIMS, was acquired and extended so chemical data could be easily integrated with the entire system. Internally developed data models (when applicable) follow the S-57 standard for hydrographic data transfer. [S-57 is a digital data format standard.] The most relevant developed data model supports the hydrographic data warehouse (HDW). This database stores bathymetric soundings acquired by the IHPT and represents a major improvement in the cartographic production process because it reduces production time, eliminates procedures susceptible to human error, and improves the quality of the final product.

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

**Data policy**

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

**Metadata**

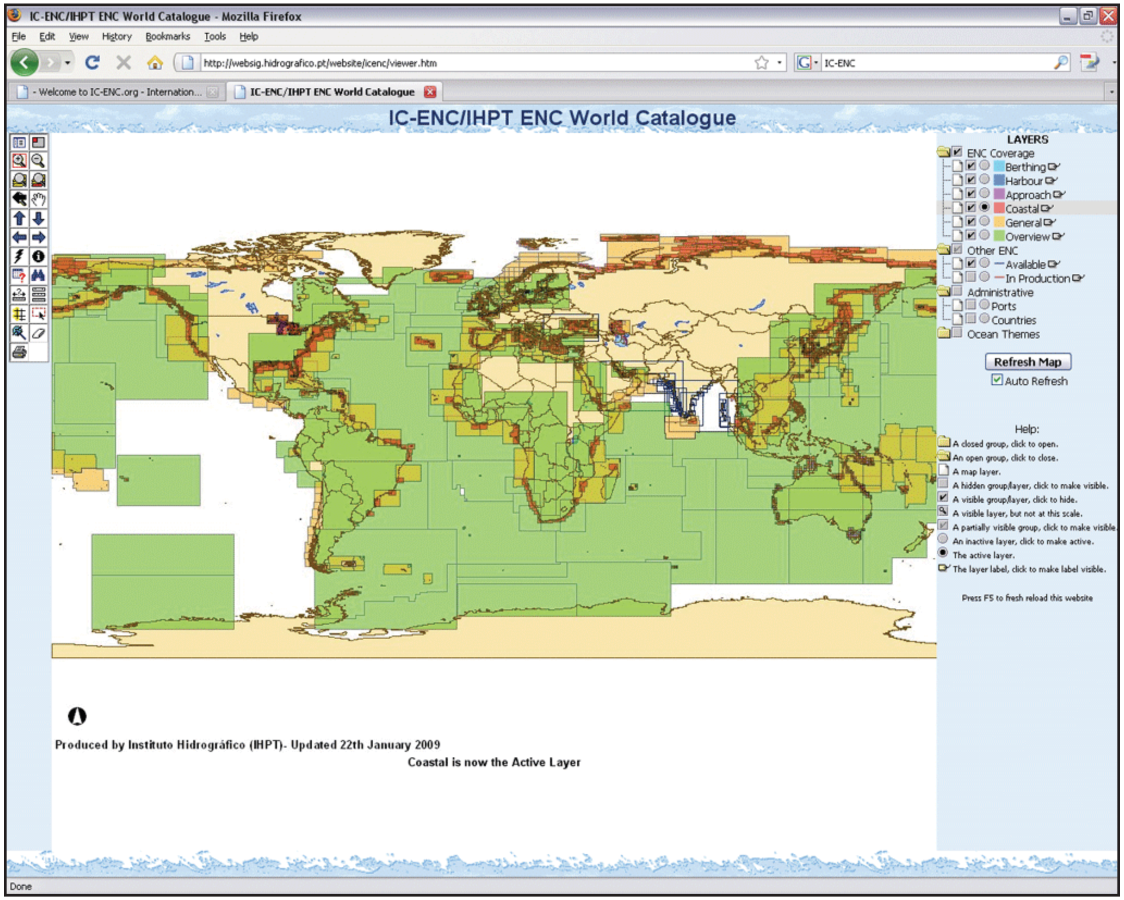
Metadata fact sheets are essential for inventorying, locating, and assessing the quality of geospatial data. These documents, which contain information about why, when, and where data was originally collected, are valuable from both a scientific and economic standpoint because they enable data reuse.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

**Specialized human resources**

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

**Outreach**

Because some geospatial analysis tasks should only be performed by scientists, courses that range from three to five days were developed to introduce scientists to GIS concepts and software. These courses are tailored to the needs of scientists and help spread GIS knowledge throughout the organization's scientific community while also providing tools that enable scientists to use GIS independently. This has allowed the organization's specialized staff time to work on both the SDI and advanced information projects.




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

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

**Hardware**

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

**Internal processes**

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

**Offline products**

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

**Online products and services**

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

**Information Products**

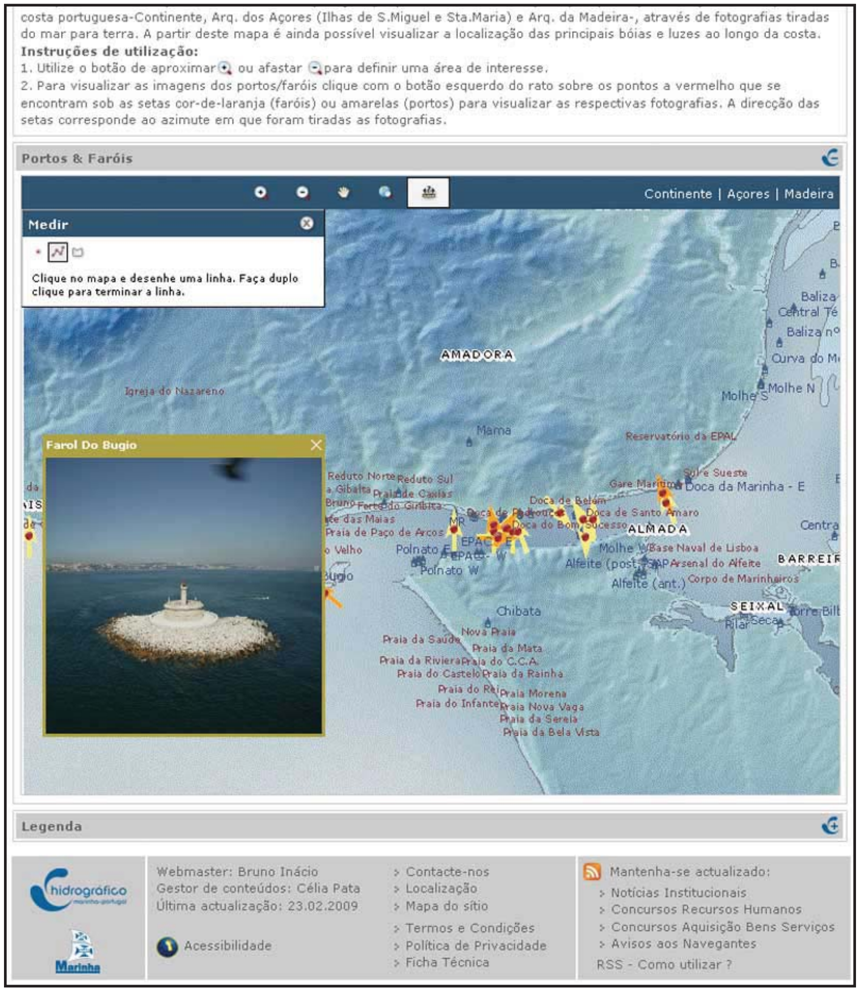
Some information products are available from one or both of the Web portals, while others are furnished offline. The scope of products supplied depends on use and encompasses public services, commercial services, environmental protection, naval missions, and research and development. The list of products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

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

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

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

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




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

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

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

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

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

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

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

### Accessing data through RSS

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

### Ad hoc independent projects

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

## Future Work

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

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

(Reprinted from the Spring 2009 issue of *ArcUser* magazine)

# The Next Step

## *The importance of building geospatial infrastructures*

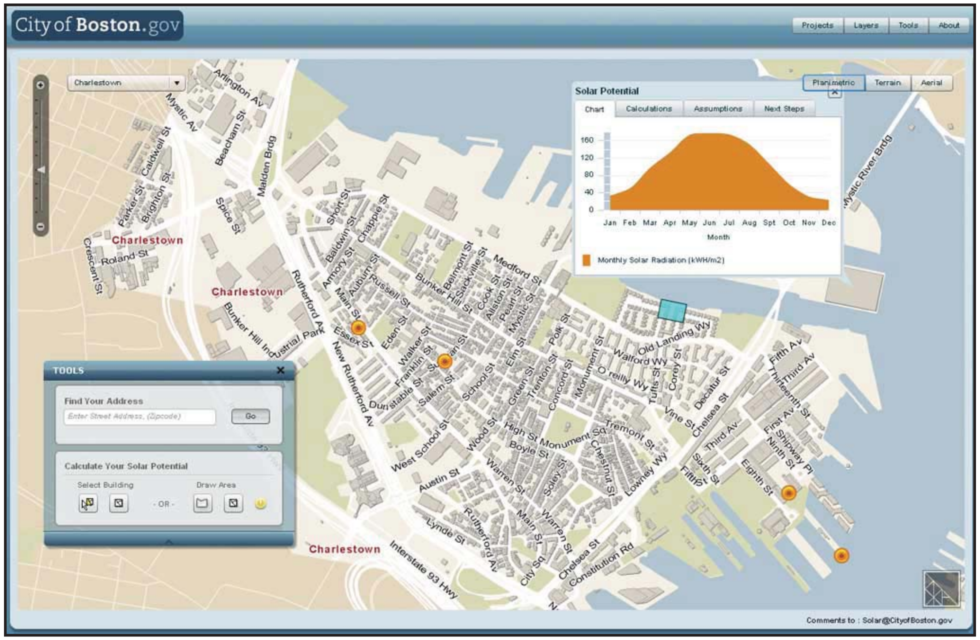
Like no other time in recent history, our world is challenged. Disease, environmental deterioration, disasters, and now the widespread disruption of financial markets test the resourcefulness of society.

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

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

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

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




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

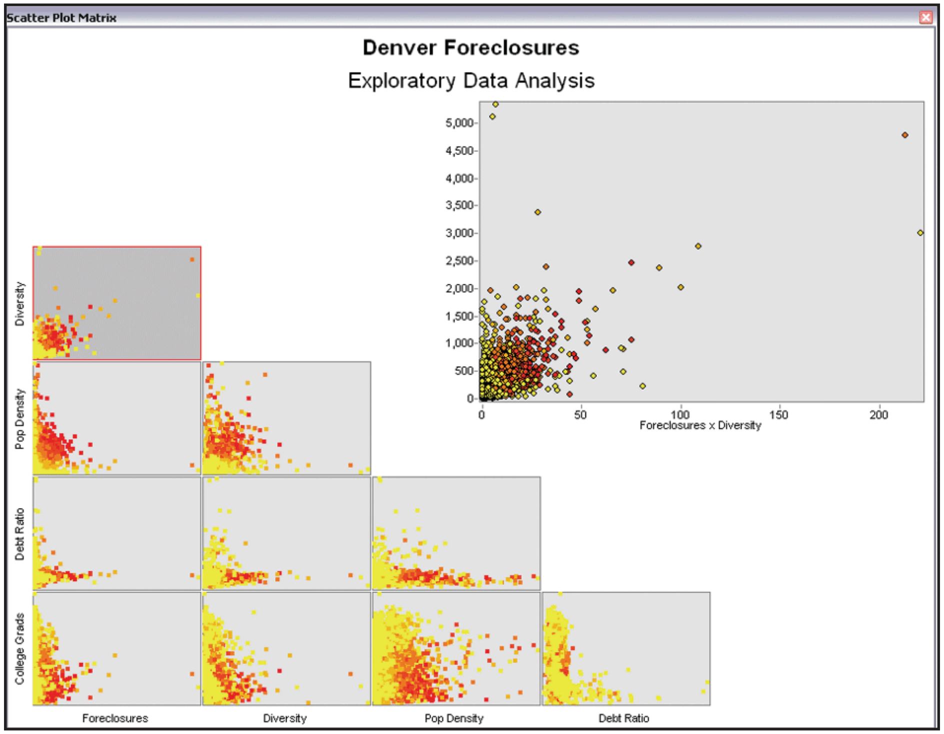
In February 2009, the Statistical Office of the European Communities (Eurostat) awarded a contract for the development of the technical components of a Web-based GIS. The contract went to a consortium that based its solution on Esri technology.

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

Building geospatial infrastructures to address complex problems provides tangible benefits.

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

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




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

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

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

(Reprinted from the Spring 2009 issue of *ArcUser* magazine)

# Improving Regional Water Quality Assessment

## *Geodatabase improves data management and analysis capabilities*

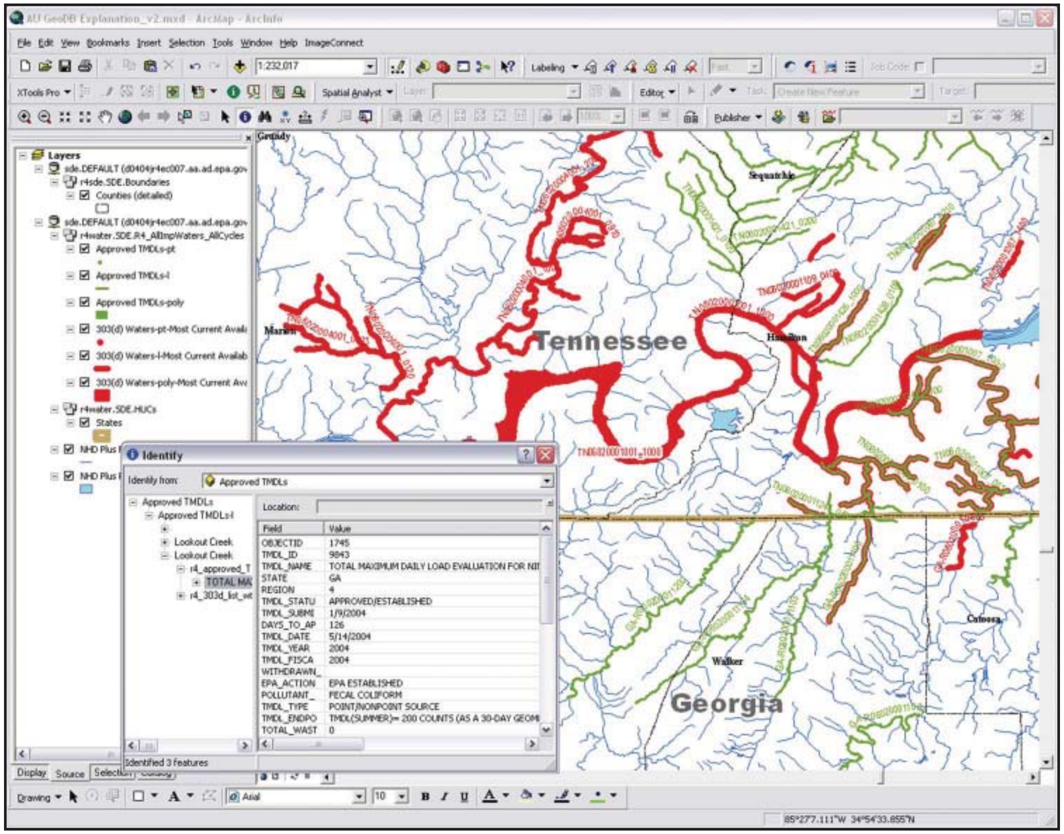
By Jon Becker, U.S. Environmental Protection Agency Region 4

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

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

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

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




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

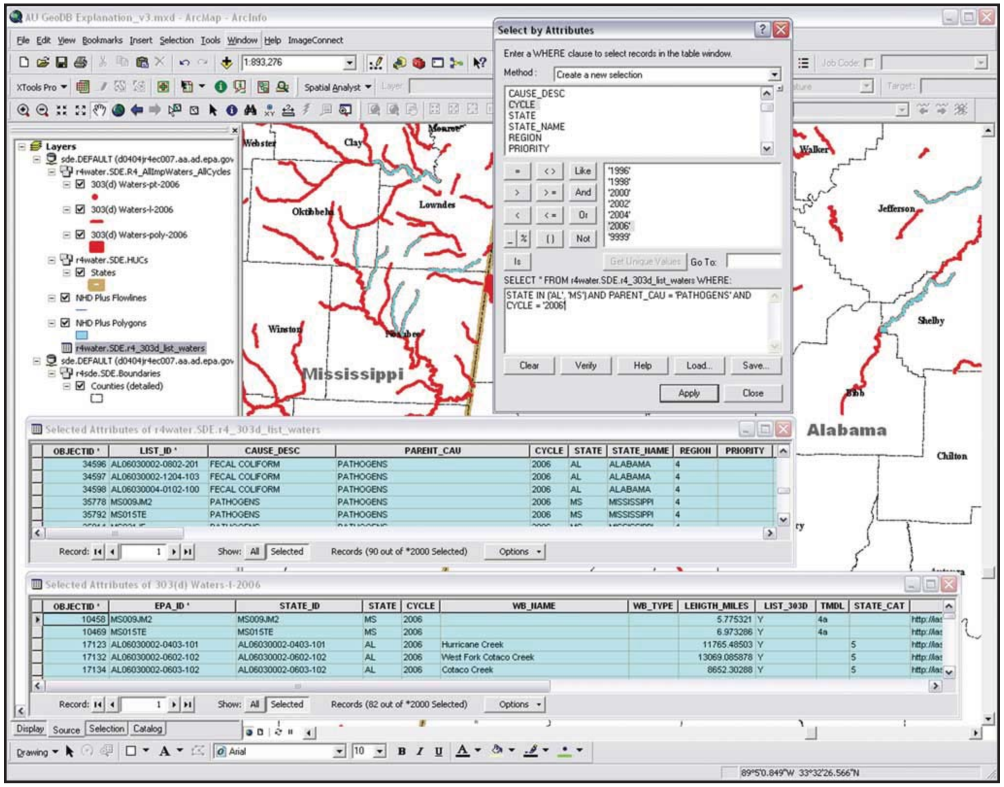
In 2007, EPA Region 4 staff explored the possibility of using a geodatabase to better manage water quality assessment data. Although data is eventually reformatted by contractors at EPA headquarters into consistent formats for inclusion in ATTAINS and WATERS, the obvious roadblock in creating a geodatabase for Region 4 was the variety of assessment data formats and GIS data used by the states.

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

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

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

However, Region 4 recognizes the value of having all state assessment GIS data in a consistent NHD-based format and continues encouraging states to adopt the NHD format as the framework for AUs. Some states, such as Florida, are exploring using a higher-resolution version of NHD to meet this need.




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

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

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

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

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

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

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

## About the Author

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

(Reprinted from the Spring 2009 issue of *ArcUser* magazine)

# Keeping Nature and Man in Balance

## *GIS data portal enables ecosystem-based management*

By Katie Budreski, Stone Environmental, and Karen Richardson, Esri

An online atlas and geoportal makes more than 400 datasets available for managing the shoreline of the North Atlantic Ocean, estuaries, and portions of two of the five Great Lakes that are within the State of New York.

*Visitors seine for fish and crabs in the shallows of the Hudson River, part of the Esopus Meadows, which has abundant aquatic wildlife and forest ecology.*

Developed by the New York Ocean and Great Lakes Ecosystem Conservation Council, the atlas and geoportal are used for ecosystem-based management (EBM). EBM is the study of activities within specific geographies with the goal of finding ways for humans and nature to coexist in a sustainable manner. Used mainly to study terrestrial environments, EBM has gained recent popularity in marine studies as communities search for solutions to ailing fisheries and ocean ecologies. Spatial data plays a key role in assisting communities practicing EBM because this management approach is place based and studies are focused on activities in specific geographies.

New York State uses EBM for managing the shoreline of the Northern Atlantic Ocean and its estuaries as well as portions of two of the five Great Lakes. To do this effectively, the state created The New York Ocean & Great Lakes Atlas (nyoglatlas.org) and geoportal (portalnyoglecc.nyoglatlas.org). The atlas is used by the general public as well as local, regional, and state decision makers to view and explore more than 400 datasets about the region. The GIS Portal Toolkit [now known as the ArcGIS Server Geoportal extension] helps visitors easily navigate the vast catalog of data accessed via the geoportal. The Geoportal extension includes a catalog service and a Web application.

## An Innovative Way to Manage the Marine Environment

The New York Ocean and Great Lakes Ecosystem Council, created in 2006, is charged with protecting, restoring, and enhancing New York's ocean and Great Lakes ecosystems while taking into account sustainable economic development and job creation. The council is chaired by the commissioner of Environmental Conservation and composed of commissioners from Agriculture and Markets, Economic Development, and Transportation, as well as the secretary of state, the president of the New York State Energy Research and Development Authority, and the interim chancellor of the State University of New York.

Stone Environmental, an Esri business partner based in Montpelier, Vermont, helped create the atlas. When launched in July 2008, the atlas was composed of a Web-based mapping application and more than 200 datasets. Users could view the datasets, download metadata and spatial data in multiple formats, and view attributes of the data. While the council had technically met its mandate, it was clear that an online catalog would be necessary to help navigate the available datasets.

## Portal Makes Data Searchable

After reviewing several technologies, the council implemented the GIS Portal Toolkit because it had—out of the box—the functionality that the council required. Sophisticated searching capabilities, the ability to establish user accounts and data provider access, and flexible metadata authoring tools were very important and readily available in the software. In addition, Esri's open software environment aligned with the council's vision for future enhancements outlined in its five-year strategy document.

*The deep-water harbor of Greenport has been a working seaport since the 18th century and continues to be a vital hub both environmentally and economically for the area.*

The portal provides a robust way for users to search all the data holdings at the atlas. Users of the portal can perform metadata searches by keyword, data type, data category, date modified, and geographic location. Information for specific areas of interest can be easily found and compared in this manner. Once found, the search results can be saved in several ways: to a user profile, to a GeoRSS feed, or as an HTML page or HTML fragment that allows users to embed a defined block of HTML inside documents at key locations. Data can also be downloaded in various GIS formats, including Esri shapefile format, via an FTP link.

## One-Stop Shop for Data

When Stone first began looking for relevant data, it discovered this was a huge task. To find the data included in the atlas, the company employed Web searches, phone calls, e-mails, and face-to-face conversations with staff from more than 300 organizations. Since the first launch, more data has been added for a total of nearly 400 searchable datasets.

Data includes administrative boundaries; elevations; cadastre; environment and geoscientific information, such as geology, groundwater, and soils; marine data, such as fish distribution and habitat, and invasive species; as well as cultural information including historic sites and settlement information.

Many datasets are from organizations that had never before distributed geospatial data widely. For example, the Facility Limit Measurement Violation data from the New York Department of Environmental Conservation (NYDEC)–Water Division provides information necessary for the Clean Water Act National Pollutant Discharge Elimination System Program that had been identified as a priority through a data needs workshop. The agency had resource and technical constraints with sharing the data internally. Providing the data via the atlas—without having to host the data—allowed this important dataset to be shared.

Facility Limit Measurement Violation data from the New York Department of Environmental Conservation (NYDEC)–Water Division provides information necessary for the Clean Water Act National Pollutant Discharge Elimination System Program that had been identified as a priority through a data needs workshop. The agency had resource and technical constraints with sharing the data internally. Providing the data via the atlas—without having to host the data—allowed this important dataset to be shared.

*Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs. These wetlands located in Wilson, New York, on Lake Ontario are an example of one of the "biological supermarkets" that can be managed using The New York Ocean & Great Lakes Atlas.*

## Publishers Control Data

When the Atlas Data Portal was first launched, the council published the data and metadata provided by the data providers. Moving forward, the council will encourage data providers to publish metadata records directly to the portal and, when possible, host their own data through subportals. Providing direct access will ensure that data is as current as possible for EBM planners and communities.

To make it easier, data providers have several avenues for easily publishing data using the portal. Records can be published by uploading metadata that has been created by a metadata editor based on Federal Geographic Data Committee (FGDC) and International Organization for Standardization (ISO) standards, like the metadata included within the Geoportal extension. Metadata can also be created using a Web form. Data providers can establish a data harvesting relationship with the portal through a subportal or Web-accessible folder. This allows the data portal to collect desired Web pages and extract necessary data.

The Tug Hill Commission GIS Data Portal (24.39.214.21/GPT9/catalog/main/home.page) is an example of a subportal. Tug Hill is a 2,100-square-mile area in a remote rural region of New York located between Lake Ontario and the Adirondacks mountain range. Several geospatial datasets were developed as part of an EBM demonstration project in the Sandy Creeks watersheds on the eastern shore of Lake Ontario. A separate data portal, the subportal, was developed so the Tug Hill Commission could manage its own geospatial data holdings but still make the data available to New York Ocean & Great Lakes Atlas users.

## Next Steps

This year, the New York Ocean and Great Lakes Ecosystem Conservation Council will work with Stone Environmental to integrate the Data Portal and Data Viewer, currently two separate applications, by upgrading to ArcGIS Server. Additional enhancements will include the incorporation of thesauruses for enhanced searching and the use of Web Map Services (WMS) and Web Feature Services (WFS) for data dissemination.

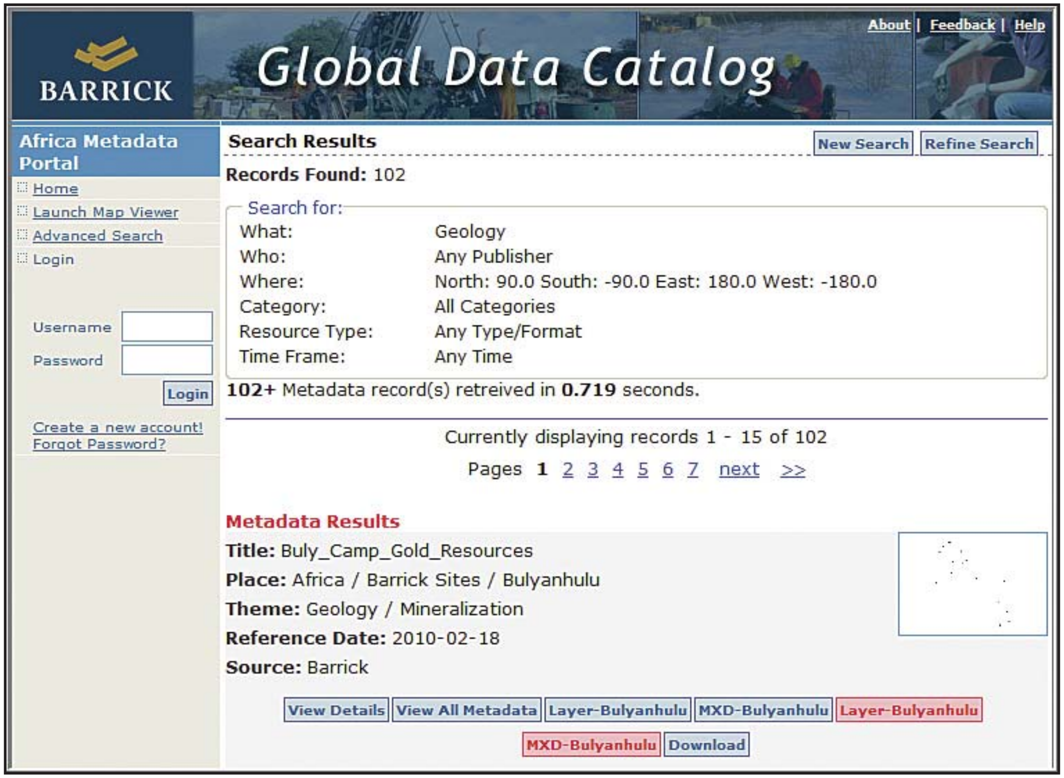
(Reprinted from the Summer 2010 issue of *ArcUser* magazine)

# Organizing a Century of Data

## *Spatial data infrastructure created by world's leading gold company*

By Matthew DeMeritt, Esri Writer

As the largest gold mining company in the world, much of Barrick's stock market value depends on its reserve base (i.e., gold proven to be minable but not yet mined). With annual gold production of nearly 8 million ounces, Barrick must add at least that much gold to its reserve base each year or its stock market value will decline. Consequently, Barrick's geological data directly affects the company's bottom line.




*Search results from a Catalog search. The Layer and MXD buttons allow streaming from the portal server, or data can be downloaded.*

## Impressive Shelf Life

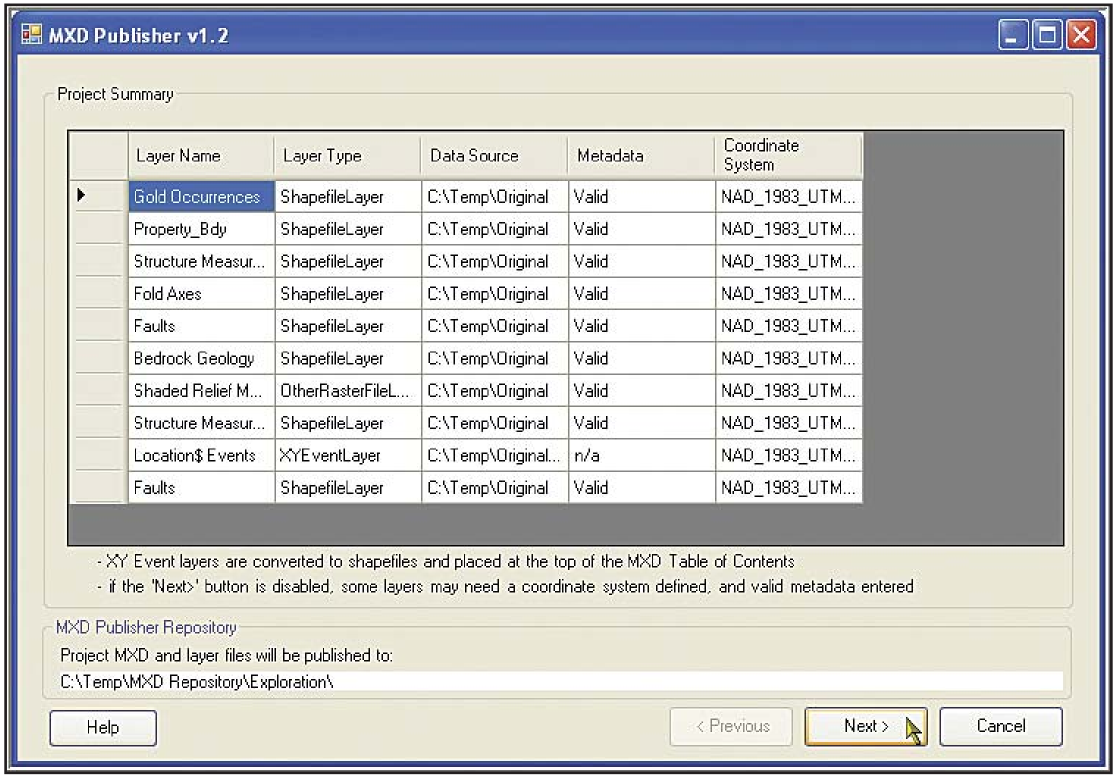
Geologic data has an unusually long life cycle. Because ore-forming processes act over millions or tens of millions of years, data collected decades ago is still relevant to any mining company. Barrick has more than a quarter century of self-collected and purchased data as well as more than 100 years' worth of data inherited from acquired companies. Effectively managing this rapidly growing collection of geology, geochemistry, geophysics, and remotely sensed data is crucial. To make best use of its impressive data archives, Barrick recently began an initiative to better organize and serve its data throughout the company, and a spatial data infrastructure (SDI) was born.

Within a mining company, different departments often have data that other groups can use. At Barrick, when surveyors collect as-built data for a mine site, that data can be of interest to the Mine Geology, Security, Health and Safety, and Exploration groups. An SDI simplifies the way spatial data is disseminated and accessed throughout an organization. "Although our vast store of exploration data was the catalyst for the initiative, the project grew to include Environment, Land, Security, and Health and Safety [groups]," said Iain Allen, global spatial data systems coordinator for Barrick. "Making every group's data available to everyone else eliminates the likelihood of duplicate data collection and/or purchasing."

## The Migraine of Fine Grain

The crucial first step in creating an easily searched data catalog is generating metadata for each dataset. However, as anyone who has created metadata knows, the devil is in the details. "Everything depends on metadata, but no one likes to do metadata," laughed Allen. "We use a custom metadata editor, MetaTools 5, by Peter Barrs of Data Arterial in Stanthorpe, Australia, which runs in ArcMap as well as ArcCatalog." Barrick standardized on 14 mandatory metadata elements and four optional ones. "We do not have dedicated data managers, so we depend on the end user for metadata. If it's too tedious, they won't do it. We tried to find a balance between everything we would like to know about a dataset and what we could realistically expect people to do."

The Barrick metadata editor uses pick lists for every metadata attribute. The pick lists automatically sync with a server-based Master Keyword Database every time the editor opens, ensuring everyone always has the most current set of keywords. Adding new keywords is done through a Web form, which adds them to the master database. The editor also facilitates the copying of metadata. Working in ArcMap, where the datasets typically have many common metadata attributes, can greatly speed metadata creation. The user completes all the common metadata elements for one dataset, copies them to all the other datasets, then completes the one or two remaining variable elements individually.

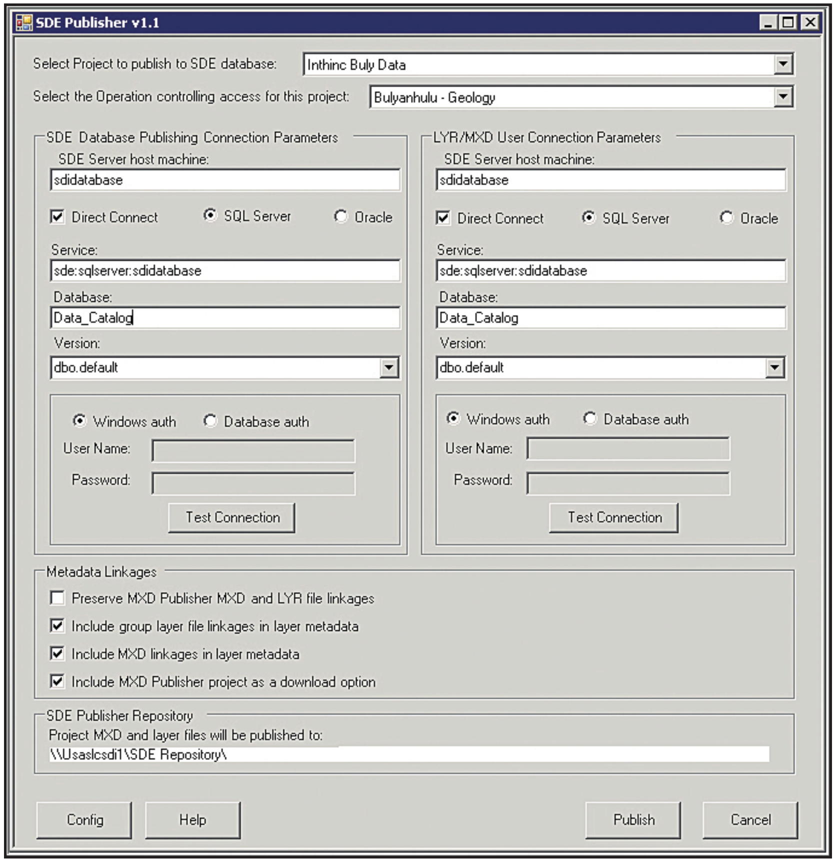



*In the first step in publishing data with MXD Publisher, all datasets are listed and checked for valid and complete metadata.*

## Publish or Perish

Detailed metadata is worthless if the data can't be queried and accessed. To publish the data, Barrick uses MXD Publisher, created to Barrick specifications by NGIS in Australia. MXD Publisher, which will not allow data to be published if it does not have complete metadata, creates a file geodatabase at a specified location on the network, also capturing all the layer files and creating a copy of the MXD that references the newly created file geodatabase. "This is our way of overcoming 'C-drive syndrome.' We find that a lot of data exists only on a particular user's laptop, so no one else even knows it exists," said Allen. "Through the MXD Publisher, all the datasets used in the published MXD are copied to the network drive. Data previously available only on their laptop is now also available, with complete metadata, on the network."

The final step in the Barrick workflow is SDE Publisher, another custom NGIS tool, that publishes the file geodatabase on the network to the enterprise geodatabase in ArcGIS Server. Each night a metadata harvester runs and updates the data catalog with the metadata for any new datasets (the data catalog uses the Esri GIS Portal Toolkit [now known as the ArcGIS Server Geoportal extension] for presentation and ArcGIS Server with SQL Server for storage). Dennis Geasan from GIS Technologies in Anchorage, Alaska, was instrumental in setting up the back-end processes.




*SDE Publisher publishes the file geodatabase from the MXD Repository to the SDE Repository.*

Search results include links to the individual datasets and to the source MXD. The results are presented with selected metadata, and buttons allow users to either stream the dataset or complete MXD directly from the server to their desktop client or download the data directly. FME Server is used for the ETL (extract, transform, and load) function, giving Barrick the ability to deliver search results in any format desired. This is important because Barrick supports two desktop GIS packages.

## Data Security

"People tend to be very protective of their data, so we have two 'data security' related metadata attributes," Allen said. One controls metadata visibility, the other controls data access. This gives Barrick the flexibility to let everyone know a dataset exists. When the metadata is added to the catalog, it will show up in search results. However, it restricts data access to the group most likely to need it. If others want access, they must contact the persons listed under the Responsible Party metadata attribute and make their case. For example, Barrick's land managers want people to know whenever there is land data available for their search area, but they do not want people to have access to that data without consulting a land professional. This procedure ensures that anyone using the data is made aware of any confidentiality or area of interest agreements associated with the land polygon.

## Future

By tagging its huge store of geologic information with metadata, Barrick has taken a significant first step in increasing the value of this data. Future work will include incorporating spatial data stored in other repositories, such as acQuire from acQuire Technology Solutions for geochemical and drilling data and EQuIS from Esri business partner EarthSoft for environmental data. Barrick will also serve data from the SDI to other applications. For example, for vehicle tracking applications, Web services from the SDI data provide context for vehicle movement.

(Reprinted from the Summer 2010 issue of *ArcUser* magazine)

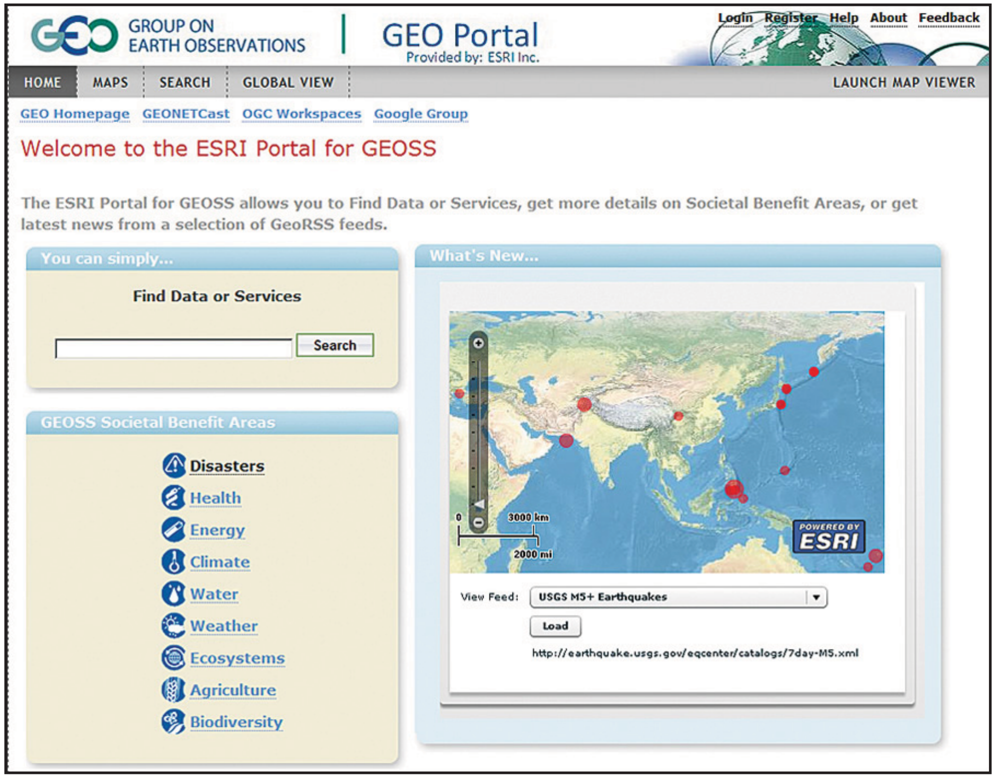
# GEOSS GEO Portal

## *Global Doorway to Understanding the Earth*

In 2003, the European Commission, along with 76 other international governments, formed the Group on Earth Observations (GEO) to strengthen global cooperation in developing earth observation systems. GEO is a voluntary coalition of governments that serves as a task force for developing new earth observation projects and coordinating strategies and investments to increase global awareness.

To achieve its task, GEO began constructing a Global Earth Observation System of Systems (GEOSS) in 2005. Based on a 10-year implementation plan that will be finalized in 2015, GEOSS will yield a broad range of "societal benefit areas" that address many major challenges facing our world. Among these societal benefits, which require precise geospatial awareness to address, are reducing deaths and loss of property from natural and human-caused disasters, understanding and improving environmental factors harmful to human health and biodiversity, and improving the management of energy resources. Of the many goals for GEOSS, one is to eliminate key obstacles to data access. GEO recognizes the need for full and open exchange of observations, guaranteed data access and usability, and a solid regulatory framework for earth observations.

Soon after GEOSS was proposed, GEO contracted with Esri Professional Services to build the GEOSS GEO Portal using Esri's ArcGIS Server Geoportal extension (formerly the GIS Portal Toolkit). The GEOSS GEO Portal offers a single Internet access point for data, imagery, and analytic software packages relevant to all parts of the globe. It connects users to existing databases and portals and provides reliable, up-to-date, and user-friendly information, vital for the work of decision makers, planners, and emergency managers. The ArcGIS Server Geoportal extension is a standards-based platform for building geospatial portals, spatial data infrastructures, and metadata catalogs. It gives GEO partners the capability to organize and publish the locations of geospatial datasets, applications, and Web resources while providing users with the ability to discover those resources and facilitating access to them (see "ArcGIS Server Geoportal Extension Manages Geospatial Resources Enterprise-wide").




*The GEOSS GEO Portal makes Earth Observation data available to scientists around the globe.*

## Conclusion

Today, the GEOSS GEO Portal provides scientists with easy access to a wealth of earth observation data and Web mapping services. It is a global doorway to increasing our understanding of the earth and helping participants move from principles to action.

## More Information

To learn more about GEO, visit www.earthobservations.org. To use the GEO Portal, visit geoss .esri.com/geoportal.

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