GIS Solutions for Environmental Management
Mapping Your Environmental Management Strategy
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Responsible and successful environmental management is necessary for protecting and restoring the natural environment. The interdependency of the earth’s ecosystems and the human impact on the environment present complex challenges to governments and businesses as well as scientists and environmentalists in every discipline.

Geographic information system (GIS) technology is used to support and deliver information to environmental managers and the public. GIS allows the combination and analysis of multiple layers of location-based data including environmental measurements. The environmental application areas of GIS are varied in terms of potential users, environmental spheres, and the specific environmental issue being investigated.

ESRI’s GIS environmental management solutions enable organizations to

- Ensure accurate reporting with improved data collection.
- Improve decision making.
- Increase productivity with streamlined work processes.
- Provide better data analysis and presentation options.
- Model dynamic environmental phenomena.
- Create predictive scenarios for environmental impact studies.
- Automate regulatory compliance processes.
- Disseminate maps and share map data across the Internet.

What Is GIS?

GIS is a powerful software technology that allows a virtually unlimited amount of information to be linked to a geographic location. Coupled with a digital map, GIS allows a user to see locations, events, features, and environmental changes with unprecedented clarity, showing layer upon layer of information such as environmental trends, soil stability, pesticide use, migration corridors, hazardous waste generators, dust source points, lake remediation efforts, and at-risk water wells. Effective environmental practice considers the whole spectrum of the environment. ArcGIS® technology offers a wide variety of analytical tools to meet the needs of many people, helping them make better decisions about the environment.
People in the environmental management community use GIS to organize existing information and communicate that information throughout their organizations. GIS can be used as a strategic tool to automate processes, transform environmental management operations by garnering new knowledge, and support decisions that make a profound difference on our environment.

GIS is considered enterprise if, by design, it is part of the overall information technology architecture of the organization. ArcGIS can be integrated with most standard corporate systems such as work management, customer service, and reporting systems. Both GIS functionality and data accessing ability can be embedded directly into other agency applications. GIS workflow applications simplify and automate procedures within environmental management operations, resulting in improved efficiency and significant time savings.

ESRI software developers and business partners work together to bring the environmental management community benefit and value from GIS. This value comes from

- Database-sharing architecture that supports decision making and daily work tasks
- Interoperable system solutions for integrated workflow and data access
- Internet mapping solutions that support interagency collaboration projects
- Quality control processes that ensure accurate, high-quality data
- Worker-friendly designs that increase agency-wide access and application
- Scalability that supports and adapts to growing and evolving IT demand

Environmental management GIS draws from many disciplines to create meaningful, intelligent maps used by a wide variety of people for a multitude of purposes.

“Public policy is being shaped by the availability of high-quality geospatial data. This increasing emphasis highlights the need for coordination, collaboration, and an enterprise view of GIS management.”

—Gregg Kreizman, Research Director, Gartner

An environmental management system requires the diversity of tools offered in ArcGIS to build virtual environments. GIS functionality is employed in spatial analysis, regulatory compliance, planning and management, map publication, and more.
The New York Power Authority (NYPA) GIS-based integrated vegetation management (IVM) program maintains approximately 16,000 acres of right-of-way (ROW) land. The program's principal aim is to provide the safe and reliable transmission of electric power in an economic and environmentally sensitive manner.

The enterprise-wide GIS ROW application, designed for NYPA by the URS Corporation, is linked to land management, environmental, equipment maintenance, and engineering data to assist managers in evaluating current vegetation conditions and prioritizing necessary maintenance. By accessing multiple geographic datasets, vegetation maintenance techniques can be selected after considering various factors including delineated wetlands, landowner rights and agreements, site access, environmental regulatory compliance, security, and dangerous tree-trimming sites. The application also has a function that supports the treatment plan review process to assess management impact on the vegetation growing in the ROW.

The program incorporates a mixture of cultural, physical, biological, and chemical management practices to control targeted, higher-growing tree species. It also works to enhance the presence of more desirable lower-growth vegetation. A regular inventory and documentation of maintenance activities allow for analysis, evaluation, and continuous improvement in the overall ROW management program.

The implementation of the ROW application now means that the process of vegetation management, from scheduling treatments to evaluating management effectiveness, is a smoother process. Field inventories are annually conducted for the rights-of-way scheduled for treatment the following year. NYPA's forestry staff members review these inventories and their suggested treatment recommendations, accepting or modifying them as they deem necessary.

Once the actual fieldwork begins, the treatment plan and related data are downloaded to field computers for use by NYPA inspectors. These inspectors track the actual treatment in the field and then upload the data to the central server for future use. When a ROW field visit is repeated, NYPA uses the as-treated data to analyze how well the previous treatment cycle worked.

John Wingfield, GIS/survey manager, reports, “On the first line where we had a repeated cycle, we saw a 60 percent incompatible vegetation reduction. Presumably, on the next cycle we will see another significant reduction. Eventually, because of our IVM program, we will be using only a fraction of the herbicides and manual effort we had used in the first cycle. We have already saved a significant amount of money in the first cycle; ultimately, we will have saved money and had an ecologically positive result.”

To learn more about the New York Power Authority’s GIS ROW application, contact Lana Khitrik of the URS Corporation at lana_khitrik@urscorp.com or Dave Frazier of the URS Corporation at dave_frazier@urscorp.com.
Combining GIS with mobile technologies, such as GPS and automated vehicle location systems, provides environmental agencies with mobile solutions that save time, focus resources, and capture accurate data.

ESRI’s Field-Based Solutions
ESRI’s mobile solutions bring office technology to the field for work processes such as surveying and vegetation inventory capture. ESRI® ArcPad® supports field data inventory tasks. ArcView® running on a Tablet PC™ allows for redlining capability with a digital pen. Redline data layer edits and annotation can be uploaded and stored in GIS for database editing. ArcReader™ provides digital file map books that can be updated at the office and disseminated to the field via the Internet. ArcLogistics™ Route is a fleet management tool for efficient routing and scheduling.

Mobile GIS Integrated Solutions
GIS and GPS integrated solutions enable field-workers to capture observation and location data at the same time. GPS and GIS technological integration is used to build new databases, maintain database accuracy, and conduct spatial analysis in the field. A GPS unit can be attached to a PDA or laptop for direct data input into GIS. The solution can be further synchronized with applications that include digital photography and date and time of data capture. Automated vehicle location can be used to track vehicle movement on a real-time map. Similar technology offered in ArcGIS Tracking Analyst can be applied to wildlife tracking of radio-collared animals.
Environmental GIS in the Public Sector
E-government GIS portal technology delivers environment maps on the Web.
Case Study—Louisiana Department of Environmental Quality

Geospatial portals are the GIS component of e-government. GIS-enabled Web portals integrate geospatial databases from different groups, making multiple databases accessible from one site. The LouisianaMAP is a GIS portal launched by the Louisiana I-Team Geospatial Information Initiative. The Louisiana Department of Environmental Quality (LDEQ) adds an environmental component to the LouisianaMAP portal (www.louisianamap.gov).

LDEQ has had a department-wide GIS in place since 1994. The GIS Center provides support to all GIS users within LDEQ and constructs maps as requested by LDEQ personnel. The center also maintains and develops GIS datasets for agency mapping requirements.

At the LouisianaMAP portal, the public can create maps, go to relevant Web site links, and read about LDEQ projects. For example, the Toxic Release Inventory, an environmental indicator, is the result of data submitted by manufacturing facilities in state reporting releases. LDEQ publishes online emission trends maps that spatially show reported air emissions data.

Water quality data is provided at the site such as the mercury program project that uses GIS to help issue fish consumption and swimming advisories. The ambient monitoring program monitors the quality of groundwater in Louisiana. Approximately 240 state water wells are included. Sampling activities and results along with the well’s geographic location are entered into the GIS to produce maps for a triennial water quality report and an aquifer summary. The atrazine project monitors and reports on groundwater affected by atrazine, which is an herbicide used to control broadleaf and grassy weeds. GIS users utilize the portal to access specific database information for many types of maps from farm management to urban development.

LDEQ GIS Center personnel use ESRI’s ArcGIS product suite and, for image processing, Leica Geosystems ERDAS® IMAGINE® software. The portal technology is built using ArcSDE®, an application server that facilitates storing and managing spatial data in a database management system, and ArcIMS®, the foundation software for distributing GIS data and applications on the Internet.

By employing tools and capabilities specifically designed to meet the needs and skill level of its users, LouisianaMAP is able to quickly deliver the information users seek within a meaningful context.

www.esri.com/environment
GIS on the Web

Web Publishing
Publishing maps and sharing geospatial information on the Internet or the intranet are invaluable to researchers, collaborators, engineers, planners, field and office workers, the general public, and others. They are useful tools for research and collaboration and open opportunities for enlarging perspectives about environmental management.

ESRI’s technology allows maps and data to be easily published on the Web. ArcIMS, Internet map server software, provides a robust, highly scalable architecture that makes it possible to publish maps and data online using XML. Clients include HTML, Java™ viewers, and ArcExplorer™—Java Edition. In addition, ArcIMS services can be accessed from virtually any ESRI client including ArcPad, ArcReader, ArcView, ArcEditor™, or ArcInfo®. This presents more possibilities for environmental management organizations to put GIS to work and get more value from the database.

GIS Data Exchange Infrastructure
Geographic databases are no longer stand-alone commodities. Government and private organizations recognize the need for sharing geographic information and are working together to develop GIS-based small- and large-scale data products that will provide the foundation for national and regional spatial data infrastructures. ESRI has worked in cooperation with international GIS and information technology standards organizations and business partners such as Safe Software. ArcGIS is based on key interoperability and Web computing concepts and is used by tens of thousands of organizations that rely on GIS and information technology interoperability.

Internet Portals
During the past decade, a network of organizations from around the world has begun to collaborate on a Global Spatial Data Infrastructure that supports the publishing of an open global library of digital geographic information. Internet portals allow people to publish, share, and use geographic data and services on the Web. These geospatial portals are made available to private, public, and commercial users; data publishers; service providers; and developers. The ESRI Portal Toolkit provides both the technology and professional support for building and managing data and applications and for deploying them in a service-oriented architecture using Internet and intranet environments.
Coral reefs in the Caribbean are threatened by many human activities. The Reefs at Risk in the Caribbean project was launched to help protect the valuable coastal ecosystems of the Caribbean by providing decision makers and the public with information and tools to manage coastal habitats more effectively. The project focuses on compiling, integrating, and disseminating critical information on these precious resources for the entire Caribbean region.

Conducted by the World Resources Institute in cooperation with more than 20 organizations working in the region, the project represents a unique, regionwide look at the threats facing Caribbean coral reefs. The collaborative process of data gathering and analysis has produced the first regionally consistent, detailed mapping of threats from coastal development, watershed-based sources of sediment and pollution, marine-based threats, and overfishing.

Wide-ranging information is consolidated within a GIS including information on coral reef locations (maps), pressures on coral reefs (observed threats, pollution, and physical impacts), changes in condition, observations of coral bleaching and disease, and information on management of coral reefs. The analysis was performed in ESRI’s ArcView software. Watersheds were delineated by using the ArcView hydrological application. Information on slope, land cover type, precipitation, and soil porosity was integrated to develop an indicator of relative erosion potential for all land areas within the wider Caribbean. This analysis was implemented using the map algebra functions in ArcGIS Spatial Analyst.

Data about four threat types—coastal development, sedimentation and pollution from inland sources, marine-based threats, and overfishing—was integrated into a single index creating the Reefs at Risk Threat Index. The threats at each location were rated low, medium, or high.

This approach permits patterns of land use within watersheds to be linked with sources of sediment transport and delivery to coral reefs, enabling those reefs at greatest risk to be identified. Maintaining healthy coral reef ecosystems and their associated biodiversity depends on applying appropriate land-use practices in critical watersheds to ensure that the impact of sediment, nutrients, and other pollutants on the coral reef system is minimized. Using this approach, it is possible to identify those areas that will be particularly sensitive to development or land-use changes and facilitate the prioritization of watersheds to ensure that the best practices are developed in areas where land-use change is most threatening to the health of coral reefs.

Special thanks to Lauretta Burke and Jonathan Maidens of the World Resources Institute for this information and the maps.
On a scientific level, GIS for environmental analysis is used to explore the spatial relationships, patterns, and processes of geographic, biological, and physical phenomena. The two primary methods of geospatial analysis include quantitative mapping and thematic mapping. A quantitative map shows how much of something is in a selected area. It is a spatial representation of numeric values such as temperatures, population density, elevation, pollution levels, and so forth. A thematic map demonstrates a specific feature or concept such as judicial boundaries, soil types, or flood zones. The combinations of data for environmental geospatial analysis are endless.

Spatial analysis employs the data-mining technology of a geographic database, or geodatabase. With it, you can document different layers of separate information sets and use spatial analytic tools to mine datasets across a diverse range of disciplines. The geodatabase provides the common data access and management framework for ArcGIS. It defines the types of data that can be used in ArcGIS—features, rasters, addresses, attributes, networks, topologies, survey measurements, and relationships—and controls how they are represented, accessed, stored, managed, and processed. The ArcGIS geodatabase offers useful features such as

- Quality assurance and control of new data can be assessed and transaction histories recorded and presented sequentially.
- Data can be modeled to allow those responsible for data management and collection to have control over its quality.
- Data can be versioned to allow multiple users to carry out simultaneous updates with long transactions.
- A variety of data formats can be filed and processed for spatial visualization.

Geospatial analysis offers insight about the environment and reveals management options. GIS incorporates powerful tools to model the relationships among geographic data for geospatial analysis. Here are some examples of tools and applications useful for advanced geospatial analysis of environmental geographic data.

**Surface Interpolation:** Visiting every location in a study to measure the height, magnitude, or concentration of a phenomenon is usually difficult or expensive. Surface interpolation functions create a continuous surface from sample locations and make predictions from sample measurements to create continuous surface representation. Use ArcGIS Spatial Analyst tools to choose the best interpretation method for your specific data. Each interpolation method produces predictions using different calculation methods from inverse distance weighted to kriging.

**Temporal Analysis:** Observing environmental change over time indicates trends and patterns. ArcGIS Tracking Analyst provides tools for display and analysis of time series data. It is useful for playing back historical data, integrating temporal data within the GIS, and charting and analyzing change in historical or real-time data.

**Three-Dimensional Analysis:** GIS constructs three-dimensional composites that can be interactively visualized. Information such as lithologic, geologic structure, and water-level data is represented in three-dimensional space by creating spatially continuous surfaces or grids using industry-accepted algorithms to interpolate between data points. This makes it possible to interpret three-dimensional data in two-dimensional space.
ESRI’s GIS Tools for Environmental Management

ArcGIS is a scalable family of software comprising a complete GIS, built on industry standards, that is rich in functionality and works out of the box.

Desktop GIS
- ArcReader allows anyone to view, explore, and print ESRI-published map files. It is designed for viewing and sharing maps that access a wide variety of data.
- ArcView focuses on comprehensive data use, mapping, and analysis.
- ArcEditor adds advanced geographic editing and data creation.
- ArcInfo is a complete, professional desktop GIS containing comprehensive functionality including geoprocessing tools.

Server GIS
- ArcSDE is an advanced spatial data server, providing a gateway for storing, managing, and using spatial data in a DBMS for any client application (e.g., ArcIMS or ArcGIS Desktop).
- ArcIMS is scalable Internet map server software. It is widely used for GIS Web publishing to deliver maps, data, and metadata to many users via the Web.
- ArcGIS Server is a comprehensive GIS server platform for enterprise and Web application developers. It is used to build distributed and multitier enterprise information system configurations based on ESRI ArcObjects’ core technology.

Other ESRI Products and Services
- ArcGIS Engine is a set of core software components and tools. It is a resources package for developers to build custom GIS and mapping applications.
- ArcPad software provides database access, mapping, and GIS and global positioning system integration to users in the field using handheld and mobile devices.
- ArcWeb™ Services offer access to GIS content and capabilities over the Web, on demand, when needed. Data storage, maintenance, and updates are handled by ESRI.
- ESRI GIS Portal Toolkit provides all the tools and templates to create a GIS portal.

ESRI products work in an integrated and flexible manner. They provide just the right software for your needs today and can be scaled to meet your future needs.
ESRI’s GIS Solutions and Services for Environmental Management

Extensions
These optional software extensions dramatically expand the capabilities of ArcGIS for environmental management.

ArcGIS 3D Analyst™
Three-dimensional visualization, topographic analysis, and surface creation

ArcGIS Data Interoperability
Uses any standard GIS data within the ArcGIS Desktop environment, regardless of the format

ArcGIS Geostatistical Analyst
Statistical tools for data exploration, modeling, and advanced surface generation and valuation analysis

ArcGIS Network Analyst
Creates and manages network datasets

ArcGIS Publisher
Converts ArcGIS map documents to published map files—useful for distributing maps read with ArcReader

ArcGIS Spatial Analyst
Advanced spatial analysis using raster and vector data

ArcGIS Tracking Analyst
Time-related visualization of existing temporal data—includes past and future time windows

ArcScan™ for ArcGIS
Raster vectorization and simple raster editing

ESRI for the Environmental GIS User Community
ESRI supports the environmental GIS software user community with educational services, professional services, and business partner solutions that help people implement and manage a successful GIS. Learn a wide range of tips and tricks for customizing environmental applications from the Online Support Center, the Developer Support Group, discussion forums, and ArcUser Online.

To learn more about GIS for environmental management, join the user group, or sign up for the Environmental Observer GIS newsletter, visit ESRI’s Environmental Management Web site at www.esri.com/environment.
For more than 35 years ESRI has been helping people manage and analyze geographic information. ESRI offers a framework for implementing GIS technology in any organization with a seamless link from personal GIS on the desktop to enterprise-wide GIS client/server and data management systems. ESRI GIS solutions are flexible and can be customized to meet the needs of our users. ESRI is a full-service GIS company, ready to help you begin, grow, and build success with GIS.

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