

GIS Best Practices

Geospatial Technology for Coastal Environments



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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.

Emerald Isle's Coastal Contingency Plan

Northern Ireland Environment Agency Quickly Responds to Pollution and Shipping Incidents with GIS

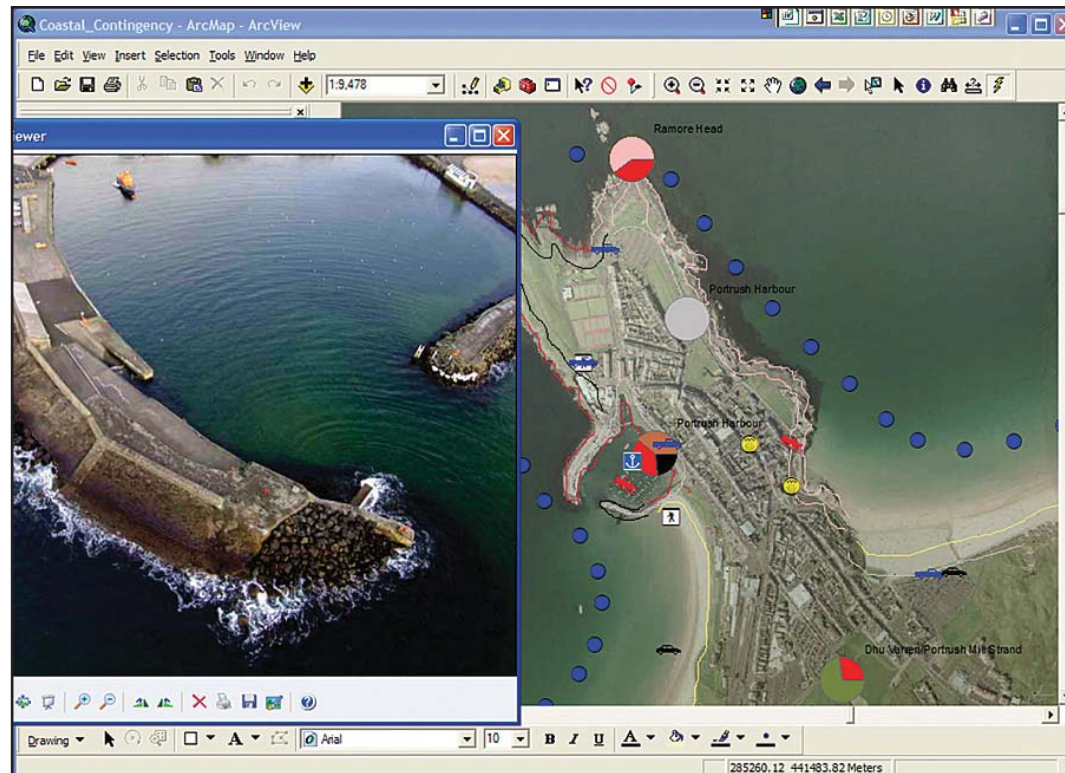
Highlights

- ArcGIS is used to create charts and graphs showing characteristics of the Northern Ireland coastline.
- Voluminous information is accessible via an online spatial data catalog served from ArcGIS Server.
- Enterprise GIS enables the NIEA Coastal Survey Team to represent more than 40 layers of data spatially.

Northern Ireland Environment Agency (NIEA) is the largest agency within the Department of the Environment in Northern Ireland, with approximately 700 staff. NIEA takes the lead in advising on and implementing the government's environmental policy and strategy in Northern Ireland. The agency carries out a range of activities that promotes the government's key themes of sustainable development, biodiversity, and climate change. Its overall aims are to protect and conserve Northern Ireland's natural heritage and built environment, control pollution, and promote the wider appreciation of the environment and best environmental practices.

NIEA is the body responsible for coordinating the response to any pollution incident that may affect the coastline of Northern Ireland and is a partner in the Emergency Response to Coastal Oil, Chemical and Inert Pollution from Shipping (EROCIPS) project jointly funded by Interreg IIIb (a European Union-funded program that helps Europe's regions form partnerships to work together on common projects), the United Kingdom's Department of Communities and Local Government, and NIEA.

The EROCIPS project aims to develop "a transferable methodology that communicates relevant information to responders and decision-makers involved in shoreline counter pollution operations following a shipping incident." In the context of EROCIPS, a shipping incident is considered to be the large-scale accidental discharge of hydrocarbons, chemicals, or inert material (timber, plastics, etc.), carried as cargo, into the coastal marine environment. The incident may result in contamination of coastal habitats and/or pollution damage to the natural, human, and built resources they support.



Ortho maps and aerial photographs are used in coastal contingency planning.

Migrating the Information

NIEA is the repository for a diverse range of coastline information concerning, for example, vehicle access points, pedestrian access points, equipment lay-down areas, wastewater treatment discharge points, coastal assets, booming sites, and National Trust areas—in total, more than 40 distinct types of data. This information is held in both hard- and soft-copy formats, sitting in disparate locations throughout the agency. On examination, all this information was found to have a spatial component, and as a result, a GIS was determined to be the ideal platform on which to integrate and communicate this information.

The challenge was to migrate all this information to a GIS platform that would enable the NIEA Coastal Survey Team to integrate all the information NIEA held on coastal assets and communicate this information to external stakeholders, such as local councils, port authorities,

Building on the Enterprise Environment

other government bodies, cleanup contractors, and waste management companies, which also play their part in the response to a large incident.

Conor Symington, EROCIPS and coastal contingency planning officer at NIEA, comments, "In 2002, I was tasked with compiling the data required to populate the data directory component of a coastal contingency plan for Northern Ireland. I spent the next 18 months or so out on the coastline carrying out surveys of all aspects of the physical coastal environment and liaising with a large variety of external and departmental agencies in order to draw together all the requisite datasets. My thinking at all times was toward producing a GIS-enabled set of layers and maps of all the data so that responders during a major coastal pollution incident (e.g., from a shipping casualty) would have at their fingertips all the necessary data and tools to mount a timely, effective, and appropriate response to the incident facing them."

After examining the technology options, ESRI Ireland, Esri's distributor in Ireland, was engaged to advise and assist NIEA in building a GIS platform to meet its needs under the EROCIPS project. To meet the objectives of the agency, ESRI Ireland carried out a requirements analysis that considered

- The nature of existing datasets and their readiness for inclusion in GIS
- How to collect new information and collate it for ultimate use within GIS
- How to synchronize and share information of common interest to multiple business units within the agency
- The technical specification of a GIS hardware and software platform that could store, integrate, analyze, and communicate this data

Following the requirements analysis, a decision was made to build on the enterprise GIS environment already implemented within NIEA. This solution is based on the ArcGIS 9 technology suite and utilized ArcGIS Server for the management, visualization, and dissemination of spatial data. ArcGIS Desktop (ArcEditor) clients are used for desktop visualization, analysis, and data capture.

Accessing and Visualizing Mapping

The solution was delivered through the development of an online spatial data catalog served from ArcGIS Server. Using ArcGIS Desktop, agency users can now access and visualize all basemapping from Ordnance Survey Northern Ireland—including all large-scale mapping and aerial photography—in conjunction with the NIEA Coastal Survey Team's own business layers that include hyperlinks to additional nonspatial data.

Rapid response is key to the effective management of any pollution incident. With the simple click of a mouse on a digital map, the agency's incident managers can now access all relevant information such as the harbor booming plans for Belfast Lough, where booms would be erected in the event of a disaster; ground-level photographs; additional aerial perspective photography (taken at oblique angles by coastal marine helicopters); and various vector datasets. Access to hyperlinked photographs of harbor piers, beach entrances, slipways, and other coastal assets will allow the Coastal Survey Team to ascertain the likely specifics of deploying beach cleaning equipment at the best possible vantage points.



Aerial photography taken from an oblique angle.

Although pollution incidents cannot be readily predicted, contingency planning is undertaken by the agency. This is where the analytic capability of ArcGIS has been particularly valuable. The system has been used to create charts and graphs showing the characteristics of the Northern Ireland coastline section by section. Users are able to view shoreline substrate types and, as a result, determine the type of cleanup response required for that particular substrate type. This allows the agency to predetermine likely appropriate responses to various incident types, thereby feeding into the rapid response at the time of an incident.

A Model of Data Management

The enterprise GIS environment has enabled the Coastal Survey Team to represent more than 40 layers of data spatially; see spatial patterns emerge; make informed decisions in planning response to minor and major shipping incidents, such as ship spillages; and visualize ship accident "black spots" and ship traffic density of the Northern Ireland coastline.

"The outcome has been extremely useful," remarks Symington. "The user-friendly desktop data management and planning tool has been as good as, if not better than, we had originally hoped

for prior to the project completion. One of the most pleasing aspects of the finished tool is that it has an in-built versatility, because not only is it loaded onto the enterprise server within NIEA and therefore can be shared across the agency, but it also has offline capabilities, meaning that the datasets and tools can be utilized in the field using a notebook PC and an external hard disk drive, without being connected to the NIEA network. Other teams have expressed an interest in following our model."

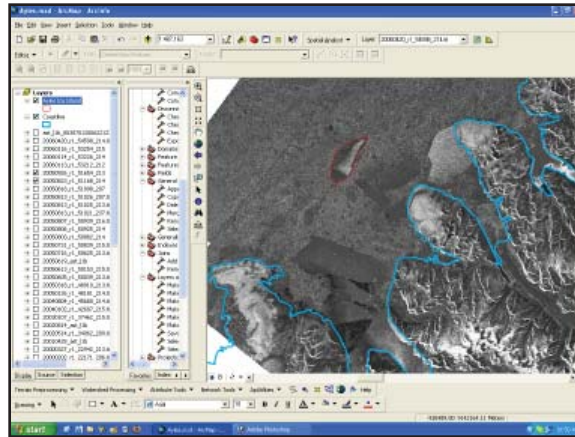
More Information For more information, visit www.eroceans.org.

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

Mapping the Ayles Ice Shelf Break

GIS Tracks 33-Square-Mile Ice Island in the Arctic

- Highlights**
- Volume of ice loss calculated with GIS.
 - ArcInfo helps visualize causes of the break.
 - Unique "microbial mat" habitat also analyzed.



Ayles ice island, delineated by a red polygon, broke from Ellesmere Island (outlined in blue) on August 13, 2005. The RADARSAT background images were processed by the Alaska Satellite Facility at the University of Alaska in Fairbanks.

It was the Arctic ice shelf collapse heard around the world: this past New Year's weekend, the BBC, the Canadian Broadcasting Corporation, CNN, the *New York Times*, and other media organizations broke the story that the ancient Ayles Ice Shelf in Canada had cracked from its mooring in an Ellesmere Island fjord and floated into the Arctic Ocean.

The ice shelf calving was discovered by Laurie Weir of the Canadian Ice Service in September 2005 while she was comparing satellite images of the ice shelves. She contacted Luke Copland from the Laboratory for Cryospheric Research at the University of Ottawa in Canada, who launched a scientific investigation into what occurred. Though the news spread in some scientific circles and was reported at a conference, journalists did not catch word of the story for 15 months.

With the possible culprit being global warming, all eyes turned north, where the newly formed ice island sits safely—so far—in sea ice about 10 miles off Ellesmere. "Right now it's frozen in off the coast," says Derek Mueller, a geographer and postdoctoral researcher at the Geophysical Institute University of Alaska Fairbanks, who helped to investigate and write a paper about what happened to the 33-square-mile Ayles Ice Shelf.

Sizing Up the Ayles Ice Shelf

Though the ice island has only traveled a short way since the August 13, 2005, incident and there's no obvious current danger to ships or oil drilling platforms, the chance of trouble ahead exists, Mueller says. "It could break away at any time and float further down to the south, and it would likely start breaking up as it floats," he states. "These ice islands will be tracked by the Canadian Ice Service so that ships will be warned," adding that the possibility exists, though slim near term, that the ice island could drift down toward the coast of Alaska with the Beaufort Gyre current and into shipping lanes and toward oil drilling operations. "Worst-case scenario, if it did hit one of the oil drilling platforms, it could cause a lot of damage," Mueller adds.

Though not enough evidence exists to blame global warming for the collapse of the Ayles Ice Shelf, Mueller says that what occurred is consistent with other signs of climate change in the Arctic. "Taken together, all of these signs are worrisome," he says.

Having studied the ecosystems on the Ellesmere Island ice shelves as part of his Ph.D. research in biology, Mueller was invited to help investigate the Ayles Ice Shelf breakup and contribute to a paper the researchers were writing about the calving. In his work, through the university's Esri campuswide site license, Mueller used ArcInfo software to create a map that helped researchers visualize the chain of events and learn how much ice was lost from the fjord on the north end of Ellesmere Island.

"The break was visible, but what we wanted to know was, What was the size of the ice island when it broke away?" Mueller says, adding that mapping and analysis showed it shrank from about 41 square miles to 33 square miles. "Aside from the loss of the Ayles Ice Shelf, 20 percent of the nearby Petersen ice shelf was also lost just after August 13, 2005. And some multiyear landfast sea ice (MLSI) that had been there since the 1940s was lost from Yelverton Bay to the west of Ayles Fjord."



Eric Bottos from McGill University, Derek Mueller from the Geophysical Institute at the University of Alaska, and Alexandra Pontefract from McMaster University sample microbial mats on the Markham Ice Shelf (August 2005). (Photo courtesy of Denis Serrazin)

After georeferencing and projecting RADARSAT images (provided to the Alaska Satellite Facility by the Canadian Space Agency and its private partners) before and after the ice shelf breakup, Mueller imported the geographic TIFF (GeoTIFF) format into ArcInfo. With vector layers, such as coastline contour lines, from the Canadian government laid down, he traced polygons over the top of the RADARSAT images of the ice shelf taken at different times.

"Using GIS, I put down several images that I could flick back and forth showing where the ice was before any of the activity, calculated the square kilometers—the area of that polygon—then looked again and saw where ice wasn't located," he says. "Then we could essentially calculate the ice loss," which was about 54 square miles, according to Mueller.



A Moderate Resolution Imaging Spectroradiometer (MODIS) image of the Ayles Ice Shelf breaking away from Ellesmere Island (August 13, 2005, at 20:45 Coordinated Universal Time (UTC)). (Image courtesy of NASA.)

"GIS also helps interpret satellite images," Mueller states. "What is good about that method is you can keep those polygons and flick the image to another time. Sort of like a time machine, you can flick backward in time and forward in time and watch for changes. And if you have a polygon or a vector overlay in ArcInfo, then you can look for your border underneath and, if it alters over time, you know you've got a change."

In studying the Ayles Ice Shelf breakup, the researchers found that factors in addition to possible long-term climate changes likely contributed to the calving.

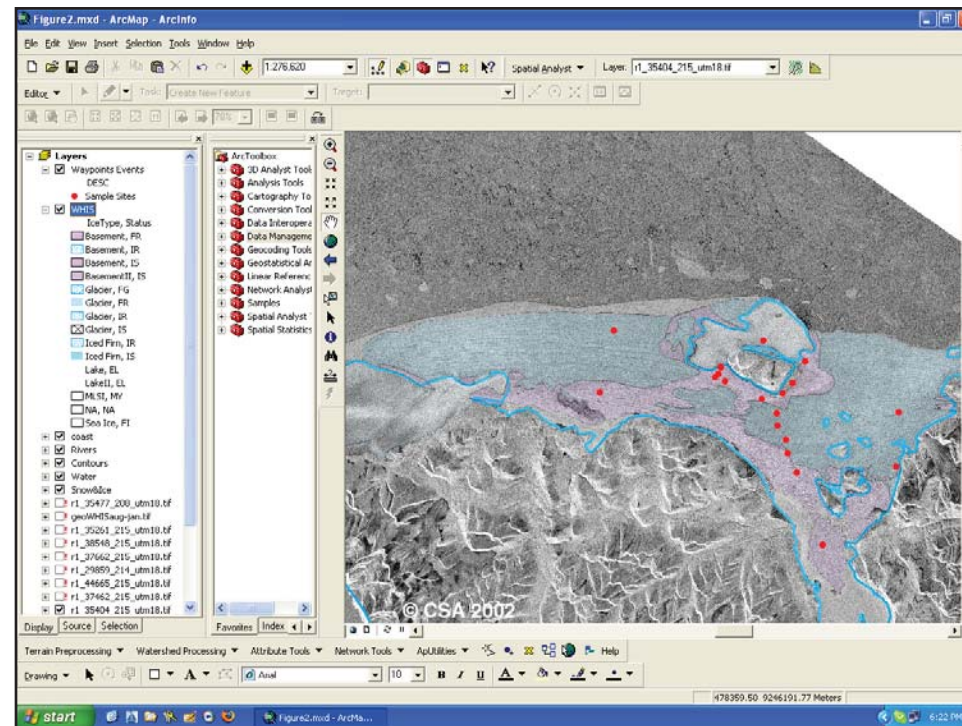
Marine scientists are still trying to understand exactly how the ocean modulates Earth's climate, and conversely how climate change affects ocean circulation, the distribution of heat, marine ecosystems, sea level rise, how changes in ocean temperature and CO₂ concentration will affect the rate of ocean

acidification, and so forth. A huge question is, How do we predict the outcomes and impact of climate change, then adapt and mitigate accordingly?

GIS is a key technology for visualizing sea level rise scenarios and potential impacts (e.g., sites of potential flooding, coastal erosion, bluff failure, adequate presence of dikes or levees, impacts on wetlands) and for analyzing how sea level rise may increase the frequency of tidal floods.

In addition to GIS tools, there are also many GIS-based portals that are helping meet the climate change challenge. One example is a coastal Web atlas, which organizes and coordinates interactive Web mapping, premade digital maps, GIS datasets, and remotely sensed imagery, often with supplementary GIS decision support tools, tables, photography, and other kinds of information, all through a single Web portal. As such, many of these atlases play an important role in informing regional decision and policy making across several themes,

In addition to higher-than-usual temperatures that summer, Ellesmere Island was struck by strong winds, according to Mueller. "A lot of the multiyear landfast sea ice broke away from the shore—from the front of the Ayles Ice Shelf—and a lot of the sea ice was pushed away as well," he says. "That was caused by very strong winds pushing offshore and alongshore. Those winds pushed away the sea ice, and that allowed the ice shelf itself the freedom to move away."



The Ward Hunt Ice Shelf showing different ice types (blue and red tints) and sites where microbial mats were sampled (red dots). The RADARSAT-1 background image was processed by the Alaska Satellite Facility at the University of Alaska Fairbanks.

"I was interested in looking at cold-tolerant organisms in ecosystems that are ice dependent," he says, adding that "microbial mats composed of algae, microinvertebrates, and bacteria are commonly found on the surface of Arctic ice shelves. The ice shelves are a unique habitat for microbial mats, which can perhaps provide some clues as to what types of life existed when the

planet was younger and how that life evolved."

In *ArcInfo*, he mapped the ice types, such as the marine "basement" ice and the meteoric or atmospheric iced firn, and also noted the sites where he took samples of microbial mats. Mueller will use that map to refer to as he continues studying the changes in the Arctic ice shelves in the years ahead.

"I'm looking for baseline information on the cryosphere—the cold parts of the earth—to look for changes due to climate warming." He adds. "Ice shelves may be a valuable indicator of climate change. When the ice shelves disintegrate, it represents a loss of habitat." He is concerned that the ice shelves may completely break up within his lifetime based on predicted warming of the Arctic.

"Working to preserve habitats and biodiversity is important," Mueller concludes. "These ice shelves may harbor some cold-adapted organisms that could be interesting for biotechnology. Or you might simply value the habitats that we are losing from our landscape."

(Reprinted from the Spring 2007 issue of *ArcNews* magazine)

There Is Still Much We Don't Know about the Ocean

"Put into a larger context, more than 1,500 people have climbed Mount Everest, more than 300 have journeyed into space, and 12 have walked on the moon, but only 5 percent of the ocean floor has been investigated and only 2 people have descended and returned in a single dive to the deepest part of the ocean. On the other hand, no part of the ocean remains unaffected by human activities, such as climate change, eutrophication, fishing, habitat destruction, hypoxia, pollution, and species introductions. Therefore, the scientific study of the ocean should be an international priority."

—Valdes, L., L. Fonseca, and K. Tedesco, 2010. "Looking into the future of ocean sciences: An IOC perspective." *Oceanography*, 23(3): 160–175.

How can we understand and mitigate the impacts of climate change, clean up oil spills, protect species, sustain fisheries, and so forth, if we still have not explored and fully understood the deepwater column and the ocean floor? The 2010 Gulf of Mexico oil spill has shown us how much ocean exploration is needed, especially in acknowledging that there was indeed an underwater plume of oil and how to track and understand its impacts.

The application of remote-sensing techniques *in* and *on* the ocean will make further exploration possible. Examples of remote sensing *in* the ocean include towed acoustic sensors, vertical line arrays, omnidirectional acoustic sensors that can sense in all directions with one acoustic ping, multibeam sonars on ships, and upward-looking sonars towed under ice. In the water column, as well as on the ocean bottom, there will continue to be small autonomous underwater vehicles (AUVs), larger remotely operated vehicles (ROVs), and still larger human-occupied vehicles (HOVs, aka submersibles), all with the ability to georeference observations and samples for many geospatial applications.

—Dawn Wright

(Reprinted from *GIS for the Oceans*, Esri Best Practices series, January 2011)

Oceans Are Key to Earth's Climate

Marine scientists are still trying to understand exactly how the ocean modulates Earth's climate, and conversely how climate change affects ocean circulation, the distribution of heat, marine ecosystems, sea level rise, how changes in ocean temperature and CO₂ concentration will affect the rate of ocean acidification, and so forth. A huge question is, How do we predict the outcomes and impact of climate change, then adapt and mitigate accordingly?

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—Dawn Wright

(Reprinted from *GIS for the Oceans*, Esri Best Practices series, January 2011)

Autonomous Underwater Vehicle Mission Planning with GIS

The U.S. Naval Research Laboratory at Stennis Space Center, Mississippi

Highlights

- NRL creates custom solutions.
- GIS helps cut through computational complexity and difficult visualization for better decision making.
- NRL can integrate its existing legacy software with advanced solutions.

Today, there is much concern about human impacts on the environment. Often, however, it's vital to focus on the environment's impact on humans and their activities. When considering the environment's impact, mission planning for underwater vehicles is a complex process. To make realistic predictions of a mission's achievability, one must take into account such factors as bathymetry, currents, water density, waves, boat traffic, and geopolitical boundaries. Distilling this information into a visual process where an operator can rapidly make decisions is a daunting task. The goal of the research described in this article is to make this a simpler, yet more informed, process.

The U.S. Naval Research Laboratory (NRL) at Stennis Space Center, Mississippi, has developed a mission planning and monitoring system prototype that incorporates the impact of the ocean environment on mission performance for underwater vehicles. As with aircraft missions, consideration of the environment is paramount for underwater vehicles, and a flexible, common, standards-based software system is needed.

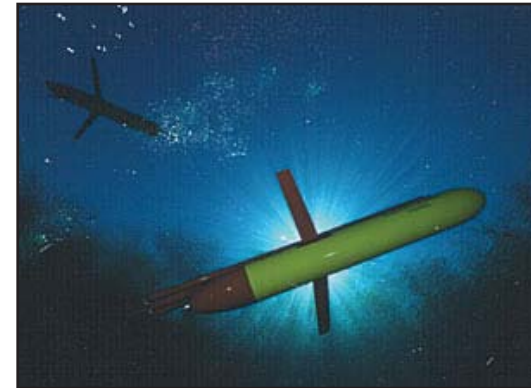
One type of underwater vehicle that is managed by this system is called a glider, a type of autonomous underwater vehicle (AUV) that is particularly susceptible to environmental conditions. This vessel does not have any propeller or mechanical propulsion system. Rather, it has a bladder, and the filling and emptying of this bladder allows the vehicle to ascend and descend in the water; wings attached to the glider body generate forward motion as the buoyancy is altered. This allows the gliders to expend little energy, and thus the missions they carry out can be extended for months

over large expanses of the ocean. However, this mode of propulsion realizes speeds of less than a knot, which is less than the ocean current in many areas of interest.

The state of the art in underwater mission planning is typically custom-made, vehicle-specific software systems that marginally incorporate environmental conditions. These packages are based on different languages and toolsets and typically comply with few, if any, existing standards. For the organization purchasing these systems, this results in independent mission planning and monitoring software for each different type of vehicle and the high life cycle costs that are typically associated with custom software. Economically, it makes sense to move toward a standard command-and-control system.

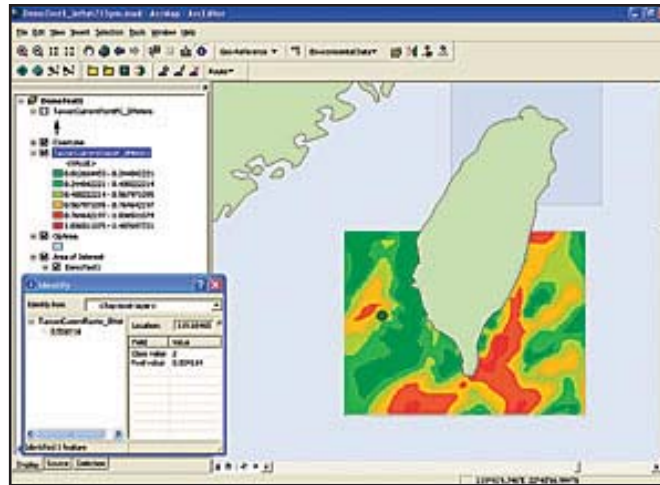
NRL examined current systems and concluded that mission planning and monitoring are fundamentally exercises in geospatial/temporal decision making. Consequently, the supporting software should be built on a GIS foundation, as opposed to the existing practice of adding ad hoc GIS capabilities to existing custom-made and vehicle-specific command-and-control systems. The Commercial Joint Mapping Toolkit (CJMTK), provided by the National Geospatial-Intelligence Agency (NGA), is the U.S. Department of Defense's standard GIS and thus a natural choice for the development of a common mission planning and monitoring system; the foundation of CJMTK is the ArcGIS Engine framework.

By having a system built around CJMTK, NRL's customers will enjoy significant cost savings for life cycle maintenance. NRL is realizing significant development savings due to the extensive functionality already provided, including data ingest and management; coordinate conversions and projections; common symbology; standardized geographic user interfaces (GUI); and multilayer operations, control, and visualization.

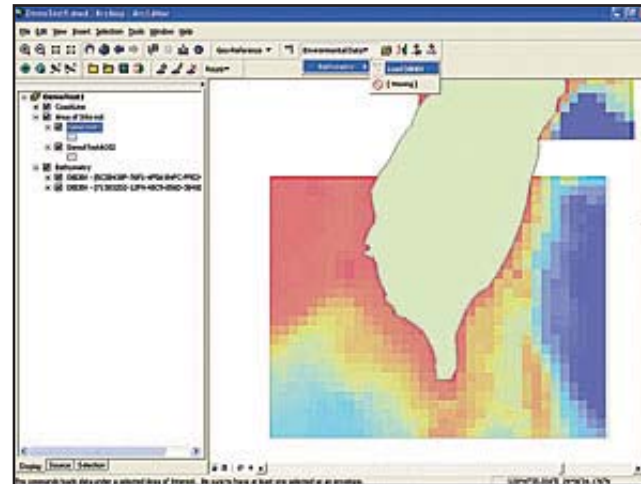


Two views of the Slocum Glider autonomous underwater vehicle.





Because mission planning and monitoring are fundamentally exercises in geospatial/temporal decision making, the supporting software is built upon a GIS foundation. Top: The numeric value of the current magnitude (loaded as a layer) is under the green dot. Bottom: Loading bathymetry.



Most of NRL's development has been in the .NET environment using the C# language to interact with the ArcGIS Engine object framework, creating custom solutions. This is being done by making use of the geodatabase, ArcGIS Spatial Analyst, ModelBuilder, and geoprocessing tools to create, store, and perform analysis and comparisons on both raster and feature datasets.

As mentioned, the task of underwater mission planning is complicated. During a mission, one is dealing with navigating a vessel in a three-dimensional volume and factoring in time-variable conditions, such as current, vehicle energy state, and ocean-sampling goals. Consequently, the decision space is represented by a three-dimensional volume over time (thus 4D), with N constraints: a 4D x N decision problem. All of this creates significant computational complexity and a very difficult visualization process for decision making.

Because NRL is trying to facilitate rapid decision making, it is not necessarily interested in displaying every parameter to the decision maker. For example, salinity and pressure to establish water density, current intensity, and current direction are used to determine what areas are navigable for the vessel. NRL, however, only wants to display the impact this data has on a proposed mission, so it has devised a method using a familiar icon, which it calls Traffic Light Analysis (TLA), for this process. With TLA, NRL takes all the data it has and, using user-specified constraints on that data, computes what volumes in the 4D mission area are within those constraints (i.e., navigable for the vessel). Rather than displaying multicolored, multidimensional, time-variant figures to the user, the system simply displays a two- or three-dimensional volume. This volume is divided into "go" and "no go" sectors.

Further, by compressing the time variable, NRL is able to significantly flatten the decision space and reduce the data size by a factor of 1,000. With the resulting TLA, if a decision maker can visualize a clear path area through the mission space volume, then a path can be constructed for the vessel with a reasonable expectation of mission success. However, if there is no way to get from point A to point B in this collapsed volume, NRL must factor time into the planning equation. This results in a slightly more complicated visualization problem for the operator, as some volumes may be navigable at certain points in time and nonnavigable at others. Still, NRL has reduced the original decision space to a much more manageable one that can be easily understood by the mission planner.

Historically, most of the software written to perform these planning functions was written in C for the UNIX operating system. By using the ArcGIS Engine object framework, NRL has been

able to integrate the existing legacy software as a temporary solution while it develops more advanced, native solutions.

In addition, NRL can also use fuzzy logic to allow it to represent areas of uncertainty. Obviously, some constraints are "hard" constraints, such as the ocean floor and land masses. Currents, either in an awkward direction or at a high velocity, are often considered softer constraints, and fuzzy logic can help NRL represent this.

NRL's initial work has shown that its staff's intuition was correct: building this mission planner on top of CJMTK has allowed NRL to not only share information with colleagues more easily but also create a more intuitive mission planner.

(Reprinted from the Winter 2007/2008 issue of *ArcNews* magazine)

Contiguous Coastal Mapping Provides Critical Marine Information

The Pacific Northwest ShoreZone Project Maps 100,000 Kilometers with GIS

- Highlights**
- Datasets and imagery are essential for resource planning.
 - In Alaska, approximately 47,000 kilometers of shoreline are mapped or being mapped.
 - As various pieces of the shoreline are connected, increased opportunities to develop regional models emerge.

Coastal and Ocean Resources Inc. (CORI), based in Sidney, British Columbia, Canada, has been supplying professional consulting services to the geologic and environmental sciences industry since 1987. Its focus is the marine environment from the coastline to the deep sea. Of the many projects this group has undertaken, one of the most significant is the ShoreZone coastal habitat mapping program, which has been widely used in the Pacific Northwest over the past 20 years.

The program is a coastal habitat mapping and classification system in which low-altitude georeferenced aerial imagery is collected specifically for the interpretation and integration of geologic and biologic features of the intertidal zone and nearshore environment. The system's datasets and imagery provide a critical backbone for a variety of applications and uses, from resource monitoring, planning, protection, and consumption to hazard mitigation and policy formation. The ShoreZone coastal mapping program has involved a wide-ranging partnership of scientists, GIS specialists, Web specialists, nonprofit organizations, and governmental agencies. CORI has executed most of the field programs, including information management, data processing, and product deliveries, with project partner Archipelago Marine Research Ltd., based in Victoria, British Columbia, Canada.

The project was originally developed in the early 1980s by the Province of British Columbia as a physical habitat mapping system that was applied primarily as an oil spill response tool. Since then, the entire coast of Washington (~5,000 km) and British Columbia (~38,000 km) has been mapped, and an aggressive inventory program is under way in Alaska with approximately 47,000 kilometers of shoreline mapped or being mapped.

In the 1980s, ShoreZone consisted of paper maps and associated tables. To enhance efficiency, by the mid-1990s, the Washington and British Columbia inventories were converted into GIS data using ArcView. CORI has since continued to move forward with Esri technology to take advantage of new developments in ArcGIS Desktop and ArcGIS Server technology. Since it started using GIS, CORI has been able to map approximately 10 times the amount of coast that it was able to process before.

"The move to GIS enabled us to capture and manipulate many times the amount of data that we were able to previously and has made the process of data maintenance, analysis, and sharing more efficient and accurate," says John Harper, marine geologist and CORI president.



The dark band at the water's edge is an eelgrass bed that can be classified and mapped and becomes part of the 47,000-kilometer Alaska ShoreZone dataset.

Before moving to GIS, CORI's database of choice was inherently detached from the maps, so linkages were vulnerable. Now, incorrect linkages are immediately flagged, which saves many hours that were previously devoted to data proofing while dramatically improving data accuracy. The classification and mapping system is based on oblique aerial video imagery and still photography of the shoreline that is georeferenced, time synchronized, and collected specifically for the project. At the time of capture, this imagery is accompanied by continuous, simultaneous commentary by a geologist and biologist aboard the aircraft that is later used to assist with the vector data creation and mapping of the shoreline. Imagery is targeted for low tide during the lowest tides of the year so that most of the intertidal zone is exposed when the imagery surveys are performed. By capturing imagery at extremely low tides, CORI is able to map substantially more shoreline information.

The imagery is interpreted initially by geomorphologists who segment the shoreline into discrete units of homogenous morphology (form and substrate type) and exposure. The units are digitized in ArcView and the physical attributes recorded in the geodatabase. Then the dataset is passed to biologists who interpret and record observed biota (such as intertidal organisms, subtidal algae, and some subtidal fauna) for each shore unit.

Once the data capture process is complete, program partners (often government and not-for-profit organizations) use this data internally, and some post it to their online sites. ShoreZone data provides a spatial framework for coastal and nearshore habitat assessment on local and regional scales. Individual resources, such as eelgrass occurrence in Prince William Sound, can be displayed and plotted, or combinations of resources with multiple attributes can be displayed together to reveal new information, patterns, and trends. For example, substrate type and wave exposure levels are used to predict shorelines sensitive to oil spill retention.

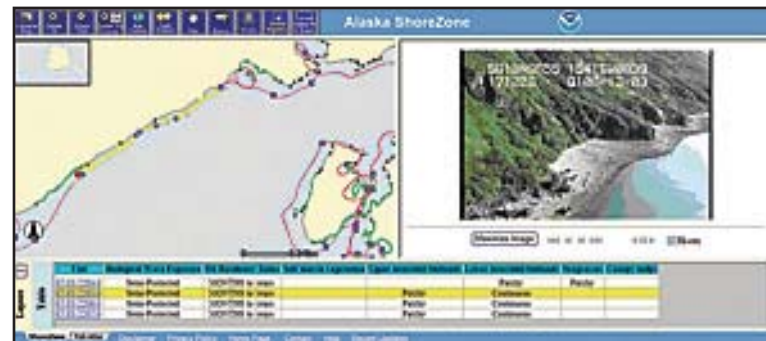
"The dataset is being used in all sorts of applications that we never anticipated," says Harper. "Recreational users find the online imagery especially useful in trip planning for kayak expeditions, fishery managers use it to identify shore-zone attributes of high-value spawn sites, and oil spill contingency planners are able to identify accessibility of the shore to alternative types of response equipment."

These applications are critical to support the efforts of online site visitors focused on ecological sustainability, environmental hazard mitigation, and public use of these areas for recreation and education. The dataset is particularly useful for regional marine planning programs such as The Nature Conservancy's (TNC) Bering to Baja marine conservation initiative, where sensitive or

rare habitats are identified. TNC can identify these habitats and add their locations to its land acquisition strategy.

Using GIS, CORI is also able to create a standardized digital shoreline so that its data integrates seamlessly with clients' thematic data. Because clients are quoted a unit mapping price per kilometer of mapped shoreline, a standardized digital shoreline is essential to quickly determine costs. GIS enables the client to immediately see the extent of shoreline to be mapped for its planned level of expenditure.

"ShoreZone has been a great tool for making the Alaska coast more accessible," says Sue Saupe, science director of the Cook Inlet Regional Citizens Advisory Council and original proponent of ShoreZone in Alaska. "By making the imagery and data Web accessible, the project has attracted many nontraditional users that don't have access to GIS, while sophisticated GIS users appreciate the richness of the dataset that now extends along thousands of kilometers of shoreline."



The Alaska ShoreZone Web site is hosted by NOAA. The left panel shows the aerial flight track and locations of still photographs; also shown is shoreline with eelgrass (highlighted in green). The right panel shows the image player, allowing the user to "fly" the shoreline.

This dataset provides a framework that underlies detailed site-specific research and supplies a tool for tying together a wide range of nearshore studies. Ultimately, the Alaska ShoreZone program has so many applications that it has helped build capacity for the overall coastal programs and develop partnerships among organizations that may not have typically coordinated their goals in the past.

By adding a spatial element, GIS has made a significant scientific contribution to the program. For example, in late 2009, Harper assembled a 20,000-kilometer shoreline dataset as a deliverable for the National Oceanic and Atmospheric Administration (NOAA). Through the use of GIS, he was able to determine that important fish habitats, including salt marshes, eelgrass beds, understory kelps, and canopy kelps, collectively accounted for 87 percent of the shoreline. Scientists always had an ecological understanding of these habitats but no idea where they were located and how much existed.

In January 2010, the Alaska ShoreZone Partnership was presented with the Coastal America Spirit Award at the Alaska Marine Science Symposium, an annual gathering of about 800 scientists and researchers. The Coastal America Spirit Award recognizes exceptional projects that demonstrate the spirit of teamwork for group efforts that are poised to address challenging coastal issues.

Future Plans

An exciting new CORI project is to develop a nearshore habitat model using ArcGIS for the Queen Charlotte Strait that is based on observed ShoreZone data. This nearshore model, which predicts substrate, slope, and biotic assemblages of the shallow nearshore area, will serve as a planning framework for nearshore mapping projects, targeting sensitive habitats for higher-resolution seabed multibeam and videography surveys.

(Reprinted from the Winter 2010/2011 issue of *ArcNews* magazine)

NOAA's GIS-Enabled Web Site Helps Resource Managers Navigate Legislation

Atlas Improves Collaboration, Coordination, and Decision Support

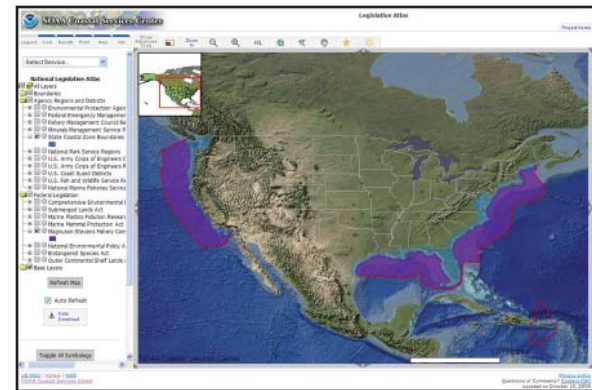
By Matt Freeman, Esri Writer

Ocean and coastal management involve a complex and multilayered system of laws, organizations, and strategies. Authority is fragmented among a variety of federal, state, and local agencies, which can result in redundant efforts, inefficiency, and confusion. In 2004, the U.S. Commission on Ocean Policy recommended a series of fundamental changes to improve the management of the United States' coastlines.

The commission, established under the Oceans Act of 2000 and with a membership appointed by the president, recommended revisions at the national level and established regional ocean councils to encourage regional collaboration. The commission also recommended forming regional ocean information programs to provide easy access to current research, ocean observations, and other information and tools to inform decision making.

Based on these recommendations, the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (which works with other federal agencies to bring information, services, and technology to the nation's coastal resource managers) set sail with the geographic information system (GIS)-based Digital Coast: Legislative Atlas (www.csc.noaa.gov/legislativeatlas/).

The innovative Web site allows resource managers to better understand the complex legal jurisdictions and regulatory framework of the nation's oceans and coasts by visualizing information in a dynamic, custom-built, Web-based mapping application.



The Legislative Atlas searchable Federal Data Viewer returns State Coastal Zone Boundaries and their spatial relation to the Magnuson-Stevens Fishery Conservation Act.

Linking Maps and Laws

Created and managed by a team of six people at the Coastal Services Center, Legislative Atlas gives users the ability to view the geography associated with ocean and coastal laws and the potential relationships that exist between these laws. The atlas is available to the public but targets resource managers involved in regional ocean management and related initiatives at the federal, state, and local levels.

Legislative Atlas provides access to geospatial datasets that represent the spatial footprint of ocean and coastal laws. When using the atlas, resource managers can query and view the spatial relationships between legislation and other pertinent marine boundaries to analyze gaps and overlaps in a region's regulatory framework. The atlas also contains the regions, districts, and planning areas of federal management agencies with respect to ocean and coastal activities. The ability to visualize these planning areas helps resource managers identify contacts within federal agencies for a particular area of interest.

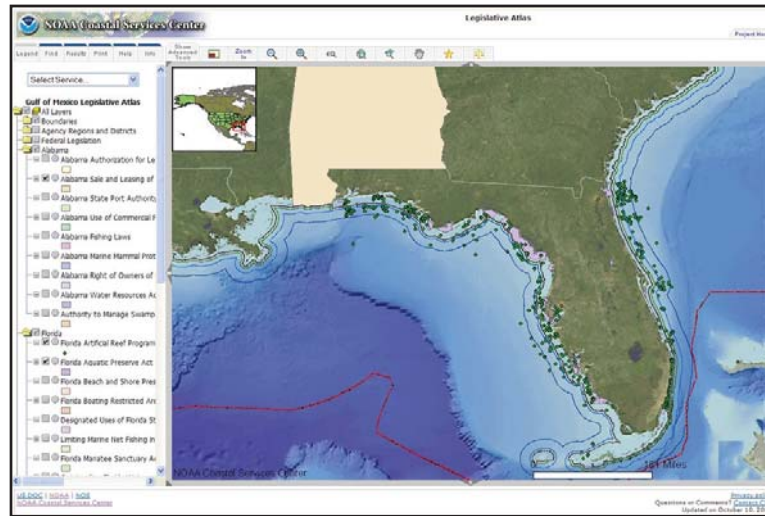
Using ArcIMS, the Coastal Services Center and Florida-based geospatial solutions company Photo Science created the atlas as an easy-to-use, dynamic mapping tool for managers with little or no exposure to desktop GIS technology. Resource managers with experience and access to desktop GIS software can download the spatial data presented online.

Legislative Atlas also features a database of relevant coastal and ocean laws that are geographically searchable. Using the mapping application, resource managers can search federal and state laws and read summaries of each law via links to the supporting U.S. codes or state statutes. The search can be refined by state, region, management issue, or federal agency of interest.

"We used to plow through piles of federal statutes in order to find the statute we were looking for and then match it to the appropriate boundary," explained Henry Norris, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission. "We have boundaries in our own GIS holdings, but we don't have the statute tied in with the boundary, and that is what Legislative Atlas offers. It's one-stop shopping. We find the area that the statute applies to and then the statute itself on the same Web site. The atlas also saves time by defining the statute. It's pretty quick."

In one instance, a colleague phoned Norris from an off-site meeting looking for information regarding the Submerged Lands Act, its boundary, where the boundary crossed Florida waters, and under what agency's jurisdiction it fell. Using Legislative Atlas, Norris was able to find the

boundary, link it to the legislation, and define the area as his agency's jurisdiction. "It took a couple of minutes to find it all," said Norris. "The Legislative Atlas probably saved me about an hour in that case because normally I'd have to use multiple resources for all of that information."



Users can view multiple layers of boundaries and legislation on one interface.

Although Norris located the geospatial data and statute he was looking for, the atlas' legislative index is far from complete. Prioritizing the relevant legislation that gets mapped is a lengthy process for each region. Continuing to develop the Legislative Atlas relies on collaboration among and targeted outreach to regional councils, resource managers, and NOAA staff. Due to the project's giant scope, new data will be added in milestones. Currently, federal laws are available for most of the continental United States, and state laws are available for the Gulf of Mexico region. The next release of data, scheduled for fall 2008, will include federal laws for the entire United States, including Hawaii, Alaska, the Great Lakes, and Pacific and Caribbean Islands; and state laws for California, Hawaii, Maine, New Hampshire, and Massachusetts. State laws for other regions, including Oregon and Washington, are scheduled for release in 2009.

"Regulations, ordinances, and rules are inherently spatial," added Norris. "They all have boundaries. One rule applies up to a certain line. Beyond that line, another rule applies. For resource managers, rules are a logical thing to see in a map environment."

For more information on Digital Coast: Legislative Atlas, visit www.csc.noaa.gov.

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